Fish Tagging via RFID and Bluetooth: Field Testing and Lessons Learned

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***Abstract*—Conventional tagging methods using plastic streamer tags have been the most widely used tool for elucidating fish movements in the last half century. These methods for fish tagging and tracking are error-prone for tracking global fish populations due to the requirement of fishermen to log details of each catch while they are also attempting to perform all of their usual at-sea activities. Under the current method, fishermen are required to remember the time and location of the catch, the size of the fish, and the weight of the fish. In addition, to report a previously tagged fish a fisherman is asked to cut off and keep the tag from the fish. In both cases the fisherman must go back and submit a form with all relevant detail, which often depends on information they try to recall from memory of events earlier in the day or even several days before. The long delay and relative difficulty associated with catch and data entry creates a barrier to data collection and poor data logging. Building on the work of the Olin College of Engineering Intelligent Vehicles Laboratory, Point Road Solutions, LLC, in partnership with the Large Pelagics Research Center (LPRC) and the Pacific Islands Fisheries Group (PIFG) have been developing a more streamlined, automated method for fishermen reporting data from fish tags while at sea.**

In the new process, a fish is tagged with a modified streamer tag carrying a rice grain-sized RFID chip. A fisherman can scan the tag at or near the moment of capture with a compatible RFID reader, which will transmit the fish's tag information to a personal smartphone pre-installed with our reporting application (Hawaii, or HI Tag App). The application then appends the tag ID with information, e.g., location, date and time, from the phone. From the application, the fisherman has the option to save the form directly as generated, correct or input any missing data (length, weight) or add richer data (e.g., a photo of the fish) before saving the form and storing the data on internal memory. When the application detects a cellular or wireless connection, the data will be immediately uploaded to the Pacific Islands Fisheries Group database. Initial tests conducted off the island of Hawaii (summer 2016) demonstrated that the HITag application greatly improved the process of fish tagging and reporting when compared to conventional manual methods of data logging. However, data entry required heads-down time on the vessel while working with the phone app, a fairly high level of precision when inputting data (on the phone), and regular interactions with the RFID reader between logging events. Fishermen partners who participated in testing deemed this inappropriate, by the and recommended a simpler, more streamlined process compatible with working conditions found on a fishing vessel at sea. To that end, our interdisciplinary team modified the app and also created a new, custom-designed RFID reader designed for use in the kind of challenging environment found on a small working fishing boat at sea. Additional hardware and interface testing was then conducted in the summer of 2017 off Kona, Hawaii, with two fishing vessels, captains and crew members in order to expand testing as well as user feedback. Tag data was uploaded to the Pacific Islands Fisheries Group tag data portal. The team then conducted a post-mission interview and debriefing with our fishermen partners to determine what aspects of the new generation tagging system were improved, and which elements of the system and process they found effective or not useful or expedient.

***Index Terms*—RFID, fisheries, fish tagging, marine biology**

I. Introduction

Many fish species, such as tuna and billfish, are considered vital in socioeconomic and cultural perspectives for communities throughout the globe. Consequently, information about marine species' behavior - migration patterns, spawning grounds, etc. - are critical to fisheries science and management missions of conservation and sustainability. In spite of increasing attention paid to the marine environment and technological advancements that enable obtaining richer data with faster means, fisheries tagging programs have seen little advancement since the 1990s [1] . In order to improve data collection, the Olin College Intelligent Vehicles Lab, in partnership with the Large Pelagics Research Center (LPRC), and the Pacific Islands Fisheries Group (PIFG) has been developing an alternative system to fish tagging: a platform called HITag that incorporates RFID technology with the widespread popularity of mobile applications. After initial successful testing in 2016, the HITag project was picked up by Point Road Solutions, LLC, and has been further developed based on feedback we received from our fishermen tagging partners. Promoting a smart and sustainable fish tagging and tracking approach will support accurate data collection and enable the continued sustainability of fish stocks for the future.

II. Large Pelagics And The Fisheries Management Problem

Large pelagics, the tunas and billfish, are highly migratory species of fish that occupy near-surface to meso-pelagic (e.g. up to 1200 m) deeper regions waters of the ocean [3] and include some of the most important fish species from an economic, social, and cultural perspective. These fish primarily include tuna (yellowfin, bigeye, albacore, etc.) and billfish (blue marlin, striped marlin, etc.) species. Despite their importance, it is still difficult to gather data on such highly migratory species. Developing the best possible understanding of their migrations and habits is crucial for accurate population assessments. In the current tagging practices, scientists and fishermen insert plastic and vinyl dart tags into the dorsal fin area of the fish. Before releasing the fish, they record data about the time, location, weight, fork length, and tag ID of the landed catch on a paper data card. Fishermen who are not directly working with a scientist are asked to mail the information (or call the research center) to submit the information they collected upon returning to shore. Fisheries researchers rely on these programs to observe species' growth and travel patterns which directly influence decisions about sustainability and ecosystem management. Past efforts that incorporate such a tagging scheme include the LPRC's Tag a Tiny Program [4], which has led to the successful tagging of over 2,000 bluefin tuna with conventional spaghetti tags. Similarly, the well known PIFG TagIt [7] program for bottom fish and reef fish species in the main Hawaiian Islands has attained over 9000 releases from contracted and volunteer fishermen efforts, and that have resulted in new understanding of fish movements. Even these relatively modest programs have contributed tremendously towards scientific understanding. Data on the migratory patterns of these large pelagic and bottom fish species provided new information with potential economic and ecological import [5].

The disadvantage of the current tagging scheme is that the process is cumbersome, and the data collected is often inaccurate [2] [1]. For instance, the current reporting system often relies on a small fleet of inshore fishermen who may record a single release location at the beginning of their tagging effort. However, since both fishermen and fish are highly mobile, this results in inaccurate locations for tag releases. Estimations of fish length and weight may also be inaccurate as these require extra steps and time to measure with care. In light of existing technical capability, existing manual tagging systems are growing increasingly outdated, and require non-trivial commitment of fishermen to tag and report the data. The HITag platform aims to create an intuitive system in which fishermen are able to focus more on the fishing experience while researchers gather more accurate, detailed data in an efficient manner.

III. System Description

The HITag platform consists of three separate components: the HITag mobile application, the RFID reader, and the database. A successful tagging session starts by catching a tagged or taggable large pelagic or bottom fish species. Next, the tag is scanned with the RFID reader which automatically sends the tag information to the HITag mobile application via Bluetooth. From the mobile application, a fisherman or researcher can verify the tag, take a photo of the fish, and record the fork length before submitting the data to create a tag report. Once in range of a WiFi or cellular network, each tag report created by the fishermen or researchers will upload automatically to the database and be parsed to display relevant information in an easy-to-understand format.

A. Mobile Application

Given the prevalence of smartphones, a mobile application is the logical means to implement tagging activities, using already available technology to provide an interface for users to easily record and upload fish tag data. The HITag mobile application was implemented in iOS and deployed on both iPad and iPhone platforms. The app was designed to provide the core feature set of a tagging experience (e.g., the ability to view/edit a tag ID and capture/release location as well as fork length) in addition to features designed to improve on the data-set available to researchers. The improved workflow of the HITag mobile app can be seen in Fig. 1, 2, 3, 4 .

Among the app features is the ability to photograph a captured fish, enabling scientists and researchers to place a face to the ID, perhaps gain valuable insight based on viewing a photo of the tagged fish. The HITag mobile application also takes advantage of the smartphone's ability to record accurate GPS location and time stamp to autofill the fish's location and time of capture and release in the report, saving valuable time.

B. RFID Tags

Given that any future tagging technology must be compatible with current systems already in place and onboard, rice-grain RFID chips were chosen as they are easy to implement in existing spaghetti ID tags.

Rice-grain RFID chips are durable, capable of staying in a tag for the lifetime of a large pelagic or bottom fish, and are easy to read and scan with commercially available RFID readers. Most importantly, the nature of the RFID tags means that they can be implemented at scale for each of the different fisheries stakeholders involved in tagging projects. For instance, handheld RFID readers can be used to read rice-grain RFID chips implanted in conventional ID tags recaptured by recreational fishers, while RFID sensors can be embedded in a gate placed on a longline fishing vessel and used to read rice-grain RFID chips previously implanted in fish that are recaptured during fishing operations. The ability to use the same technology for all fisheries stakeholders, in every skill level of the diverse fishing communities, allows for a much broader impact. It allows fishermen the ability to tag and report their fish records more easily, and the use of the mobile application interface available through smart phones means that this data acquisition is much more accurate and accessible. Through this, we believe that many individuals and groups of fishermen will be empowered to tag and release

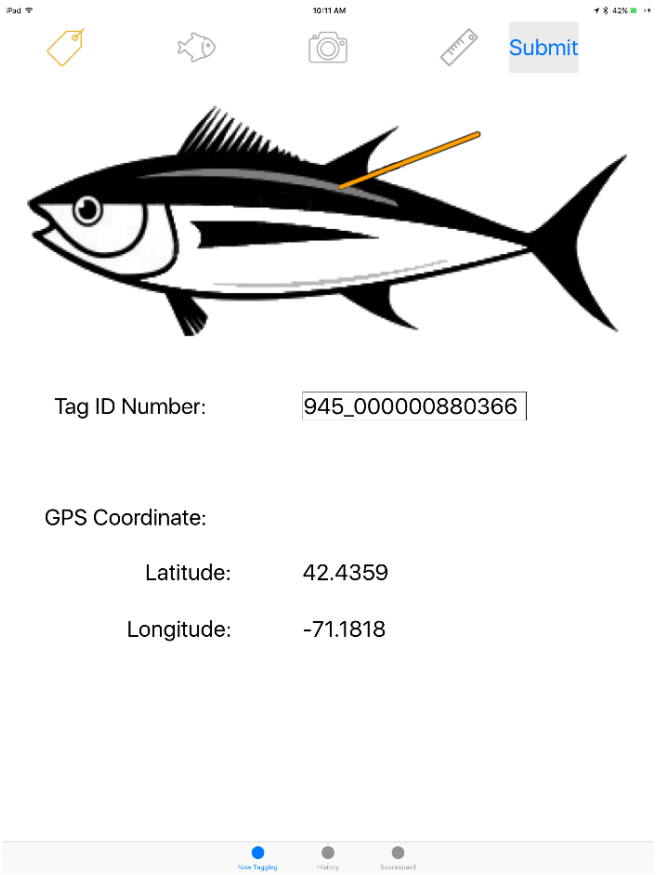

Fig. 1. The tag ID number is automatically filled in when used with an RFID reader, which automatically sends the data from the RFID reader to the mobile application via Bluetooth. The user can also manually enter the tag ID number. The app automatically fills in the GPS coordinates and stores the time at which the tag ID is read.

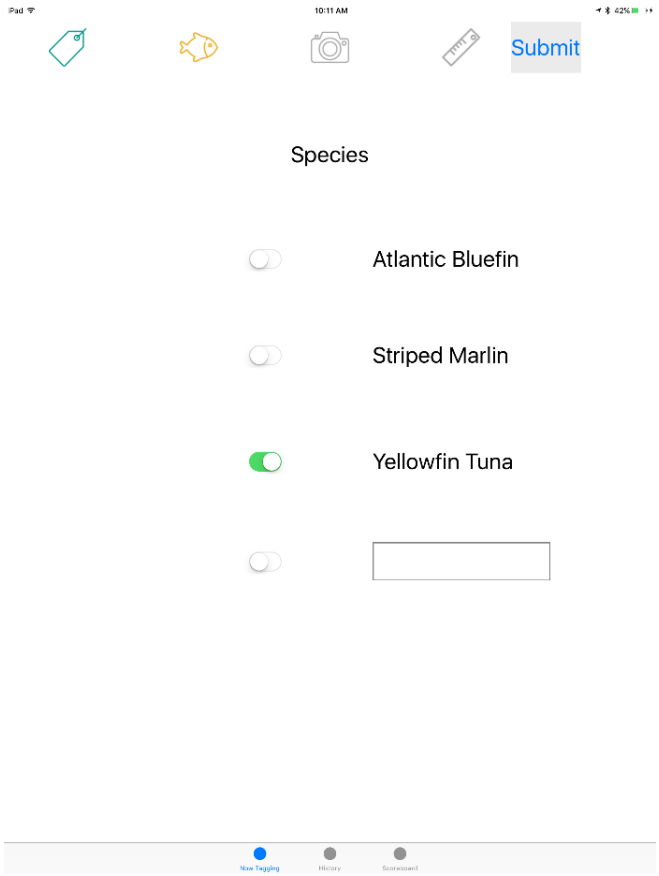

Fig. 2. The user is asked to select the species of the fish they are reporting. The user may enter a species name, if something unexpected is tagged.

more fish, in diverse fisheries where releases are desired, and submit accurate tag reports, thereby increasing the pool of valuable information available to scientists and researchers.

C. Database

While the HITag application and open access to advanced RFID technology should make it easier for fishermen to contribute to the amount of data available to researchers, this data is only helpful if it can be easily accessed and analyzed. With this in mind, we have developed a database where all tag data will be automatically uploaded and parsed upon a cellular or WiFi connection from the user's mobile application.

Living in the cloud, the database is easily viewable, allowing fisheries personnel and researchers who are part of the program to view the data from a particular fishing session just minutes after the boat has arrived back at the docks. User access to information can easily be managed and secured to ensure the confidentiality of the data sources. Moreover, we intend to implement data visualization tools in order to broaden the community of users who can easily view tag data and get a better grasp of the ocean ecosystem from the perspective of scope of movements and behavior of tagged fish. For instance, the tag data from the database could be integrated with a map, providing a broad view of the locations of recently recorded tags. Such a tool would allow researchers an at-a-glance view of tagged large pelagic species while maintaining the privacy of the fishermen.

IV. Field Tests

A. Experimental Methods

Before the HITag platform will be fully deployed within the fishing and scientific communities, testing has been and continues to be necessary in order to determine that the platform is fully functional and can work successfully in the hands of users. The first such iteration of the HITag platform was tested in July 2016 with fishermen engaged with the Pacific Islands Fisheries Group TagIt program off the coast of Kona, Hawaii. While the data quality and ease of use were both drastically improved [6], data entry required heads-down time on the ship while working with the phone app, along with a fairly high level of user interactions with the RFID reader to keep the device functioning. In addition, the reader itself suffered from a very short effective range and poor feedback response, leaving the fishermen unsure about whether or not the data had been correctly captured. Fishermen partners who participated in testing deemed this unwieldy, and

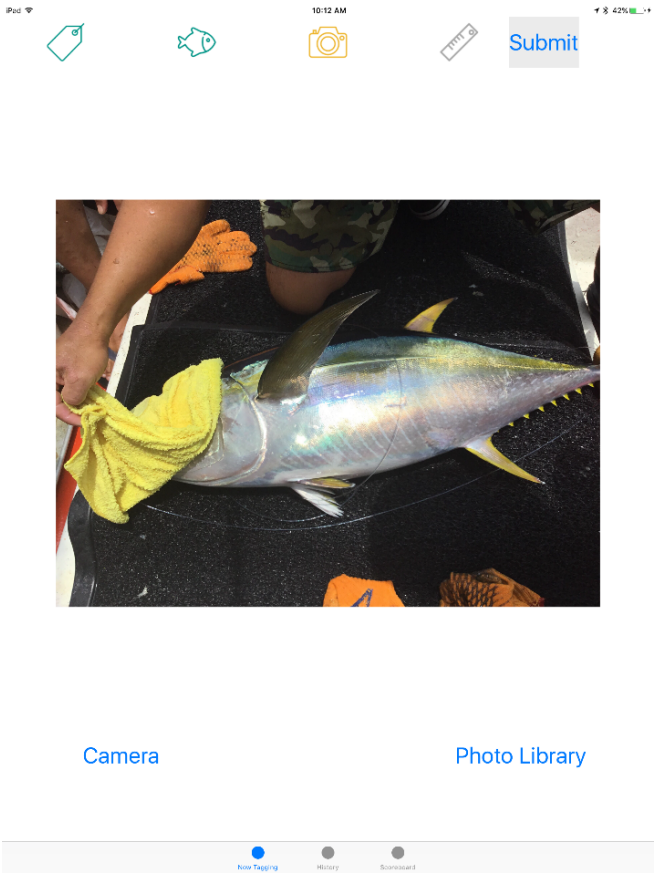

Fig. 3. The phone's camera capabilities are used to obtain a photo of the fish which can provide valuable insight to scientists.

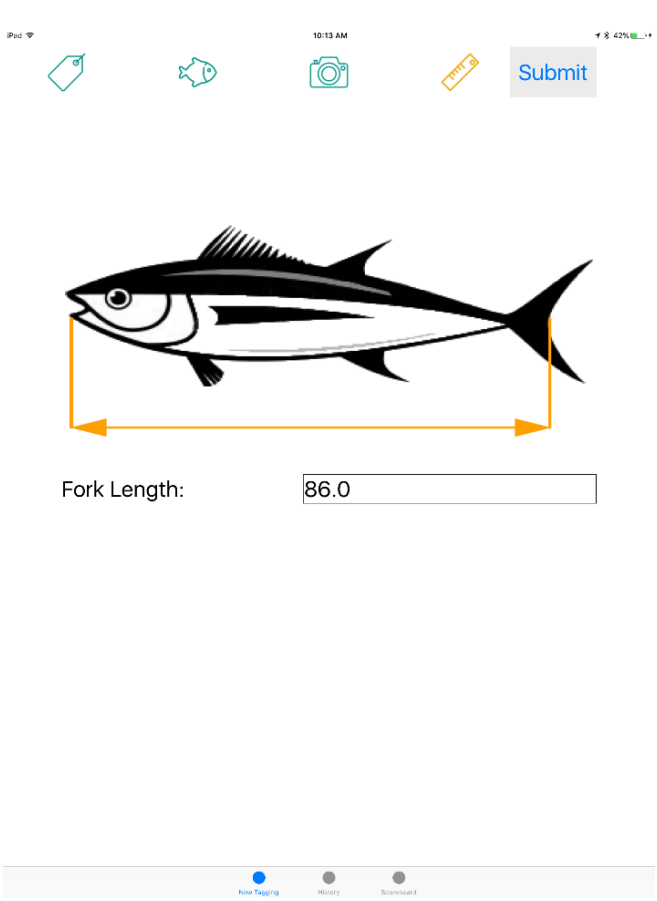

Fig. 4. The user is asked to measure the fish to track its growth.

recommended a simpler, more streamlined process compatible with working conditions found on a fishing vessel at sea. In particular, busy fishermen, often working alone, did not wish to have to find and input information into their phones at all while at sea. To that end, our team modified the 2016 app to require less interaction, and also created a new, custom-designed RFID reader designed for use in the kind of challenging environment found on a small working fishing boat. Additional hardware and interface testing was then conducted in the summer of 2017 off Kona, Hawaii, this time using multiple devices on multiple boats to increase fishermen's experience and feedback with the HITag system. Data was uploaded to PIFG's web portal at the end of the fishing day. The team then conducted a post-mission interview and debriefing with fishermen partners to determine what aspects of the new generation tagging system were improved and which did not meet expectations of functionality.

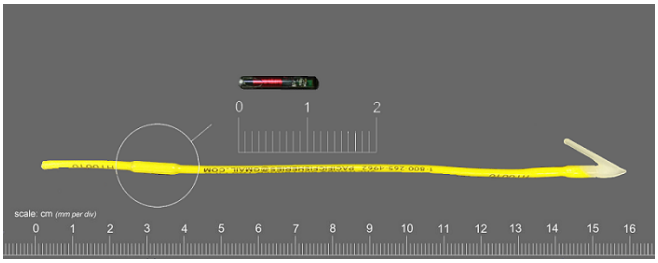

Fig. 5. The HITag uses a tiny RFID chip to automate the process of tag identification. The chip is embedded in a conventional dart tag made from nylon and vinyl.

Fig. 6. Tagging reports from the HITags application, showing the date/time of the tagging event, the tag number, the latitude/longitude at which the tag was read, the species, the fork length, and a photo of the fish.

B. Process

For the testing, our team worked from two local Kona style fishing vessels tasked with tagging juvenile yellowfin tuna (known as ahi in the Pacific) using the HITag platform in an effort to maximize the number of tagged fish in the allotted two days of field testing. Over the course of testing, the team

successfully deployed 20 tags after quickly examining and measuring the fish to be released.

In 2017 field trials, testing was conducted using two custom-built readers (see Fig. 7) which interfaced to a re-designed HITag app via a wireless Bluetooth link. The reader was designed to stay on and function all day, thereby removing the need to re-start the app or reset the two devices.

Fig. 7. Custom-built RFID Reader with Streamer Tag for Scale

C. Results

The redesigned HITag platform obtained a richer dataset than the paper notes produced by the current reporting process. The data entry method on the vessel was much easier and the wand performed at greater distances from the tag. It also simplified feedback by using a simple red/green ultrabright LED to indicate when the tag was successfully read (RED was standby/no read, and GREEN was a successful read). The entire process, from landing through tagging, measuring and releasing the fish typically took about 15 sec, with the longest time on deck associated with measuring the fish's length and taking its photo.

In a post-mission debriefing, fishermen partners noted that they rarely handle their mobile phones at sea (where there often is no coverage), and usually secure them in the wheelhouse. As a result, they requested a data entry solution that would remove the need to handle their phones once the HITag app was running. Consequently, the team concluded that it would be necessary to add additional functionality to the HITag Reader, and in particular, the capability to take a photograph.

V. Conclusion

As they are both highly mobile marine resources and deeply valuable to fishing communities worldwide, the study of tunas, billfish, bottom fish and many other species can inform us about the state of our fisheries and marine ecosystems. Based on preliminary findings and field testing, we concluded that the HITag platform has the potential to provide tremendous benefits to the community of fishermen, scientists, and fisheries managers with vested interests in the information returned by tagging programs. While the data collected was of dramatically higher quality, the system as implemented at that time was difficult to use in the field. Field testing of the second iteration has shown that the issues encountered are solvable while at the same time, improve the quality of both data and the user experience. The HITag app allowed fishermen to more efficiently tag their target catch (in this case, small yellowfin tuna) and to acquire and record desired information little-to-no detriment to their fishing experience. We believe the HITag platform has the potential to be a cost-efficient, easy to implement at scale method for conducting tag and release and data entry. By making this data easy to collect and access, the HITag platform can increase participation to a much broader community of users, inclusive of scientific, recreational, and commercial fishermen, and push innovation in the field research space.

VI. Considerations for Future Work

The 2017 development and testing effort was devoted to taking the feedback from fishermen and turning the HITag platform from an intriguing concept to a useful tool. Based on our successful field tests, the platform will continue to be iterated on and improved through testing in the field and feedback from users. Part of this focus will be to expand the reach of the platform to include the continuing development of both iOS and Android versions of the HITag app and tools for better understanding and analyzing the data found in the database. Additional research may focus on improving the tags themselves, particularly in developing more advanced satellite tag technology, further expanding the amount of data we can gather on large pelagic species and the ocean ecosystem.

Acknowledgment

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