Implementation of the *iSnapper* smartphone application to collect data across all recreational sectors in the Gulf of Mexico

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PROGRAM

Harte Research Institute for Gulf of Mexico Studies
Texas A&M University- Corpus Christi

Gregory W. Stunz, Ph.D.
David Yoskowitz, Ph.D.
Mark Fisher, Ph.D.
Megan Robillard, M.S.
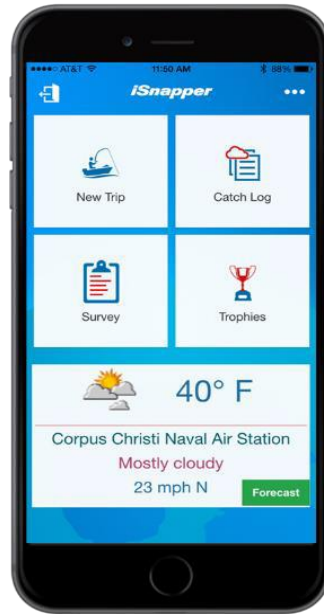Tara Topping, M.S.

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I. Abstract

One of the most difficult aspects in fisheries management is the ability to collect timely catch data from the private fishing sector to estimate total recreational harvest. The lack of timely and robust data from recreational anglers (i.e., private anglers and for-hire charters) creates management challenges and controversy, as managers seek to optimize fisheries harvest. We created *iSnapper*, a smart device application ("app") designed for private recreational anglers, to log their catch and effort information during the 2015 federal Red Snapper season (June 1st – 10th). During the 10-day season a total of 163 trips were logged using the app, and these anglers harvested a total of 1,519 Red Snapper. Additional data collected included trip length, general fishing location, fishing depth, number of anglers, and number of fish released. Self-reported data was validated by comparing trips submitted using *iSnapper* to dockside creel interviews (259), with a total of 11% of trips validated. Using a capture-recapture design along with these validated trips, we developed an estimator that showed in 2015 private recreational anglers in Texas reported 4.1% of their trips, had a harvest error rate of +5.1%, and harvested a total of 58,251 Red Snapper (± 25,344 SE) weighing an estimated 277,752 lbs. This is comparable to Texas Parks and Wildlife harvest estimates of 32,062 Red Snapper (± 4,409 SE) weighing an estimated 153,525 lbs. Also included in the app was a socioeconomic survey, with 95 unique respondents reporting their average distance traveled was 89 miles, spent approximately $200 for bait and tackle, consumed 82 gallons of fuel, and 61% had a yearly household income over $100,000. This study shows that smart device apps are a very effective method for collecting private recreational fisheries data, and when coupled with strong validation strategies these data can be used by fisheries managers to estimate total harvest of recreationally important fisheries and also examine important questions such as discard mortality, depth fished, and a variety of socioeconomic parameters.

II. Executive Summary

Red Snapper is one of the most highly targeted species in the northern Gulf of Mexico. This fishery has been classified as overfished since the late 1980's, and this designation has led to drastic reductions in both season and bag limits. Uncertain and unpredictable recreational catch rates along with a federal court ruling required managers to build in large harvest buffers to prevent overfishing, and these measures have created even shorter seasons with only 10 days in 2015. Ironically, this situation has also created a much narrower window for fisheries managers to collect catch data further compounding the harvest estimate issues.

A major challenge to improving recreational season length and alleviating some of this controversy is the lack of timely catch data. Supplementing the Marine Recreational Information Program (MRIP) with an electronic data collection system would provide more timely and robust information, thereby allowing managers to refine catch estimates and reduce buffers that could lead to optimizing the harvest and allow for longer recreational seasons. Thus, we created *iSnapper*, a smart device application designed for private anglers to log their catch and effort data. Mobile applications provide a unique opportunity to provide better data that will work in combination with current MRIP survey protocols to provide a supplementary means of rapid in-season (and out of season) catch information that would otherwise be unavailable. In addition to catch statistics, this type of reporting mechanism generates additional data that are typically difficult to collect such as fish discard rates, fishing depth, effort estimates, and socioeconomic parameters that will help optimize the fishery's full potential from both a harvest and an economic perspective. The concept of electronically collected and self-reported data certainly has many challenges; however, this pilot showed *iSnapper* has the ability to overcome many of these obstacles while generating real-time, validated, and reliable private recreational catch data for fisheries managers – something needed by all groups involved to improve access to the Red Snapper fishery.

A key component to this study was the validation of catch data submitted by anglers, with creel interviews conducted to verify accuracy of user-entered information. These data were compared to trips submitted via *iSnapper* using the vessel registration number as the key linking parameter. A majority of the data analyzed within this report occurred during the federal Red Snapper season (June 1 – 10), because there was an increased number of creel surveys and fishing activity during this time allowing for the best probability of intercepting an *iSnapper* user

for validation. From the validated trips we calculated a reporting and harvest error rate and developed an estimator (specifically for this project) to calculate the total number of Red Snapper harvested, and the total number of private recreational angler trips in Texas during 2015.

iSnapper was introduced to anglers via extensive outreach and advertising campaign employing TV, radio, print, and social media. A total of 163 trips were submitted using *iSnapper* by Texas private recreational anglers harvesting a total of 2,012 fish during the federal season. Red Snapper was the most dominate species captured (1,519; 75.5%), with all trips reporting at least one Red Snapper harvested. A variety of other species were also caught, with King Mackerel and Dolphinfish as the other most commonly harvested species. The mean reported discard rate for Red Snapper was 56.1%, with the highest rate of 74.3% occurring at depths between 21 – 30 m.

A total of 969 private recreational Red Snapper anglers were encountered during surveys at Texas boat ramps. The creels from these anglers represented 259 fishing trips and harvested a total of 2,268 Red Snapper. To validate the self-reported data, these trips were compared with those submitted using *iSnapper*. The sampling was done using a mark and recapture approach, with *iSnapper* users being recaptured during the creel survey. Of the *iSnapper* trips, a total of 18 were validated during the dockside interviews, generating an 11% validation rate. From these validated trips we calculated an overall reporting rate of 4.1% as well as an error rate of +5.1%. Using the reporting rate and error estimates from the federal season, along with creel data provided by TPWD for the entire year, the estimated total number of Red Snapper harvested by Texas private recreational anglers was 58,251 fish (± 25,344 SE) weighing an estimated 277,752 lbs by 23,358 angler trips (± 6,660 SE) in 2015. Although not the focus of this study, we had an additional 13 charter for-hire trips submitted using *iSnapper* throughout summer 2015, which was surprising given the popularity of previous versions of *iSnapper* piloted with the for-hire Federal Reef Fish permit holders. Different than private recreational anglers, charter captains had a longer federal Red Snapper season (40 days; June 1 – July 14) and during this time reported harvesting a total of 76 Red Snapper, 25 Dolphinfish, 6 King Mackerel, 1 Warsaw Grouper, and 1 Yellowedge Grouper (seven total trips). Six additional trips were submitted in August from state waters with a harvest of 128 Red Snapper, and no other species were reported.

In addition to catch and effort data, the app also collected socioeconomic information from participants. The survey was a separate feature built into the app that allowed anglers to fill

out and submit the survey, but was not linked to particular fishing trips. A total of 100 surveys were completed with 95 unique respondents. Approximately 98% of the respondents were male, with 93% residing in Texas. The average distance traveled per trip was 89.3 miles (± 7.3 SE) with a mean expenditure in bait and tackle for the trip was $197.40 (± $34.22 SE), and boats consumed on average 82.4 gallons of fuel (± 12.0 SE). These results demonstrate the utility for smart devices to collect these types of socioeconomic data that are essential to valuating the fishery.

Overall, this project demonstrated that smart device applications can be successfully designed to collect catch and effort data from the private recreational fishing sector to greatly enhance and supplement current data collection approaches. An advantage of this approach is the timeliness of the data collection provided, particularly in circumstances of shorted seasons where traditional MRIP approaches may not be as feasible. We were able to streamline data collection by gathering all the pertinent information in only a few screens making the data entry quick and easy, allowing anglers to report catch information for multiple species, as well as discard mortality, depth fished, and a variety of socioeconomic components of the fishery. The program was also voluntary, and that may have contributed to a lower than our desired reporting rate. Although mandatory reporting certainly does not guarantee 100% compliance, comparisons should be made across states where reporting is mandatory to determine how this influences the accuracy of the estimates. However, even without mandatory reporting, we found that smart device app technology has great potential to collect valuable catch and effort data quickly and efficiently from the private sector and can be used to make catch estimates. While this pilot was specifically targeting Red Snapper anglers, *iSnapper* has the potential to improve management for a variety of fisheries. By combining these smart device technologies with traditional fish survey methods, managers have improved tools to gather more information to make better informed decisions.

III. Purpose

    A. Description of the problem

        One of the major challenges to fisheries management is the ability to collect timely catch data from the recreational fishing sector. Recently, management measures have led to an increasing need for more timely and accurate estimates of recreational catch and effort data for assessing stocks (Griffiths et al. 2010). The problem is further compounded with shortened seasons and the need for rapid in-season measurements of catch. The lack of timely and robust data from this sector has created problems when fisheries managers calculate the annual harvest quota well after the season has ended and this has led to major conflicts among users for species such as Red Snapper (*Lutjanus campechanus*). This species is highly sought after by both commercial and recreational fishers and its management is one of the most controversial in the United States. For example, the inability to rapidly gauge recreational catch has resulted in the sector exceeding the allocation for the past 21 of 24 years. A recent 2014 federal court ruling resulted in federal managers implementing a 20% buffer to prevent the overages. Compounding the problem, anglers are also catching larger snapper each year; thus, reaching the quota faster than in previous years. All of these factors have led to very short federal fishing seasons (10 days in 2015, 9 days in 2014), despite anglers seeing a resurgence of Red Snapper. These shortened seasons hinder the ability of traditional approaches to collect accurate data from recreational anglers, because they were not designed to collect data in this manner. The Marine Recreational Information Program (MRIP) has modified their sampling protocols to increase the amount of data collected from anglers during these short windows. However, there is still a need for rapid in-season and near real-time data collection. Here we developed a novel data collection tool for the private recreational sector using smartphone/tablet applications ("apps") and web-based data entry portals.

        In the past decade there has been a dramatic increase in the number of people using mobile phones. With this emerging technology, a new avenue of data collection was developed using apps as the platform for data collection. The concept was initially tested in the fisheries field by having recreational anglers submit text messages of their catch and effort data (Baker and Oeschger 2009). However, the 160 character maximum severely limited what could be included in the message, making it difficult to report an entire day of fishing. Currently, nearly two-thirds of Americans own a smartphone (Pew Research Center 2015), so the next logical step

is to move from a text message data collection system to creating a specialized app that can be created and then downloaded onto the phones. More recently, smart devices have redefined the technological market allowing users to do a multitude of operations including accessing the internet using cellular data; thus, there is a high potential to use smart devices to collect more informative fisheries catch data.

Collecting data via smart device technology incorporates another recent trend using citizen scientists (individuals that are amateurs or nonprofessionals) to collect a substantial amount of data for relatively little cost. The data submitted by these citizen scientists are considered "self-reported," because these individuals are reporting without any direct validation from state or federal managers. The benefit in collecting and using self-reported data is that these citizen scientists provide managers with data that would otherwise be unavailable and they feel a sense of empowerment by being able to contribute to the conservation and management of their natural resources (Cohn 2008). Scientists are also recognizing the potential of self-reported data from smart device apps that have been created merely for entertainment purposes. One such app, *iFish*, is essentially a catch log for freshwater anglers throughout the United States and Canada. Catch and effort data is submitted by the user and this information can be used by fisheries managers to better understand local hotspots or how fishing pressures change depending on season (Papenfuss et al. 2015). We proposed and tested the potential to use this technology in the private recreational Red Snapper sector.

The Red Snapper fishery in the Gulf of Mexico is an ideal testbed to examine the feasibly of a voluntary smart device data collection app for private recreational anglers. Due to the limited federal Red Snapper season, fishery managers must rely on collecting as much data as possible from this sector while the brief season is open. Creating an app not only provides fisheries managers with near real-time data, but it can also collect a multitude of other important information (e.g. socioeconomic data, release mortality, etc.). A lack of timely data hinders the management of this fishery because data generated from directed creel surveys takes months before it is transcribed, edited, reviewed, and available for management advice. During this time, data submitted using an app could be analyzed and the total harvest could be estimated in a much more rapid fashion, allowing for in-season monitoring of the recreational harvest, which could potentially increase the season length, and reduce the 20% management buffer.

While an app provides the ability to collect more robust and timely harvest data, validating the quality is of paramount importance. The most critical and informative validation measure is to visually inspect the entire catch when it is landed dockside to confirm that submitted catch reports are consistent. This validation allows managers to calculate the reporting rate as well as error estimates based on anglers who may have, for example, misidentified certain species of fish or have inaccurately reported their total harvest. These estimates can then be extrapolated to all of the trips that were interviewed at the boat ramps to calculate more accurate total harvest estimates.

Given the potential of smart device apps to improve the management for many fisheries, our aim of this study was to supplement the current MRIP data collection program by developing and testing new technologies to enhance recreational fisheries data collection. In 2011, Harte Research Institute for Gulf of Mexico Studies (HRI) released *iSnapper* for use in the charter for-hire industry and had overwhelming success with the project with major buy-in and support from participants (Stunz et al. 2016, in prep). Due to this success, the original concept was redesigned to create an app that could be used in the private recreational sector as well as for charter captains.

B. Objectives of the project

The specific objectives of this study were to:

1) Develop and implement *iSnapper* as a data collection app (for Apple, Android, and Windows platforms including a web portal) for private recreational anglers in the Gulf of Mexico;

2) Compare *iSnapper* data from panels of private anglers to TPWD creel survey data to validate the applicability of electronic data collection;

3) Collect and assess socioeconomic data from reef fish fishery participants using *iSnapper;*

4) Provide *iSnapper* as a data collection tool for NOAA-approved programs targeting Red Snapper in the Gulf of Mexico.

IV. Approach

iSnapper development

Despite creating a very successful prior version of *iSnapper* (v1.0), it was necessary to re-design the platform to create a submission process easy and aesthetically pleasing for private recreational anglers that were not as incentivized as for-hire captains to enter catch data. Thus, working with Elemental Methods, LLC we recreated *iSnapper* (v2.0) on Apple's iOS®, as well as two new platforms, Android® and Windows®. Both smartphone and tablet versions were created for each platform to give individuals different and the most comprehensive entry options.

Application Architecture

The *iSnapper* v2.0 app was created and built upon *iSnapper* v1.0 and used to collect catch and effort data from private recreational angler boat owners, as well as charter boat operators, throughout the Gulf of Mexico. This version was specifically adapted to be most suitable to private recreational anglers; however, most of the features and data collection options were available to continue to gather these data in the for-hire sector. Anglers were asked to enter their catch data by "adding" the species captured from the provided list of all the commonly caught species in the Gulf of Mexico (Figure 1) that included easy to select images. Once a species was selected, they provided the number harvested and released individuals. The average depth fished and general fishing area were also required fields and indicated by clicking on an image of the Gulf of Mexico. Effort data was gathered by providing the number of anglers on the vessel, and fishing times were also collected. Several new features were also implemented to build a multi-functional app in a very user friendly environment to promote use by private anglers. Some of these features include current weather and tide information based on location, the ability to submit pictures of unidentified fish directly to researchers, and each trip can be shared on the individual's social media networks (Facebook® and Twitter®).
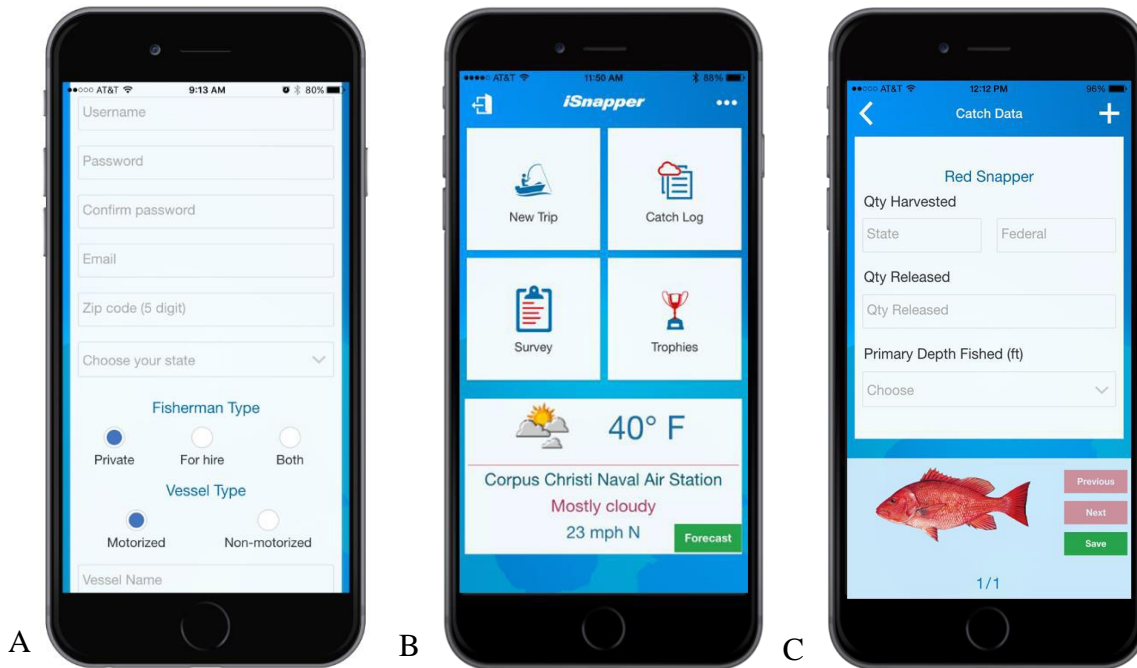
Figure 1. Screenshots of the registration screen (A), home screen (B), and the species catch screen (C).

Web Portal

Anglers were not limited to only using smart devices to submit their trips. We also created an online *iSnapper* webportal (https://isnapperonline.org, Figure 2) that anglers could use if they did not have a smart device, or potentially encountered problems submitting their catch using the app. This option provided anglers with the opportunity to register or login using the same username they created when registering on the *iSnapper* app and enter their catch information online. Additionally, the webportal allowed anglers to login and view their catch data and saved photos from previous trips. The webportal was also designed to store all user and trip information for administrator access and data download as needed throughout the season.
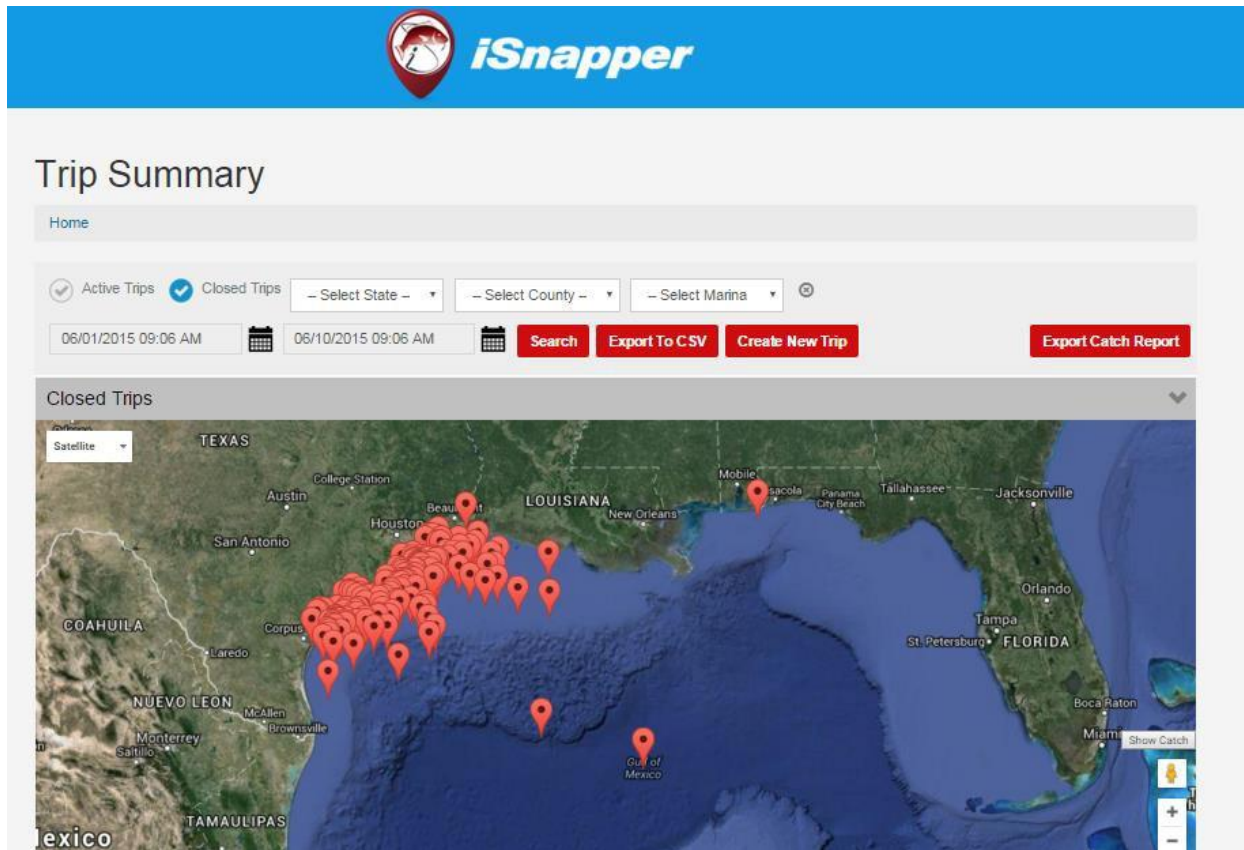
Figure 2. Image of the webportal with all trips from the federal season displayed.

Panelist Selection

A crucial portion of this study involved the validation of self-reported data. Originally, we planned on selecting a defined list of panelists from known Red Snapper anglers that represented a variety of angling frequency types using a stratified systematic random sampling design and then target these panelists at boat ramps during the Red Snapper season. However, this plan represented some insurmountable obstacles given this was the first pilot of this type. For example, we quickly discovered that a robust database of individual Red Snapper anglers that we could draw from did not exist, these anglers could not be assigned to ports of origin, and there was no information regarding their angling frequency. Thus, this initial plan was reconsidered and a new approach, and in hindsight a much better method, was developed after extensive consultations with MRIP statisticians (Lynne Stokes, Ph.D.) wherein we created a more inclusive design that involved collecting data from all *iSnapper* users, which was used as the initial "panel." Now future studies have the ability to draw from this created panel of users

that was built from known Red Snapper anglers. Briefly, the overall design was based on the well-established mark and recapture theory (Laplace 1786), where *iSnapper* registered users were considered "marked," and then "recaptured" during boat ramp creel surveys after completing a fishing trip. The initial identification of anglers was randomized by sending out postcards, media outreach, and distributing informational wallet cards to as many anglers as possible without prior knowledge of their willingness to participate in the study or with what frequency they fish for Red Snapper.

Outreach

In collaboration with media and outreach partners at TPWD, we sent two postcard flyers that provided information about *iSnapper,* to as wide of an audience as we could identify. This included the 610 known Texas Red Snapper anglers that had been identified in their long-term data set along with mailings to charter captains and other participants in the *iSnapper v1.0* pilot. The private anglers were encountered by TPWD creel surveys who had captured at least one Red Snapper on their trip during the last five years. A second mailing was also sent near the season opening to alert anglers that *iSnapper* was available for download and use. To further increase the number of *iSnapper* users, we also advertised in several state and local magazines, radio, and television news and public service segments. We also created of an informative webpage (www.iSnapper.org) separate from the data collection portal, and these information sites were pushed extensively through social media avenues (e.g., Facebook® and Twitter®) by both HRI and TPWD and created an account on two of the most popular saltwater fishing forums to inform anglers about the app. In addition, TPWD produced flyers, wallet cards, and laminated signs that were distributed to bait shops and anglers several weeks prior to the opening of the federal Red Snapper season. Before the start of the season coordinators of groups such as the Coastal Conservation Association Texas, Saltwater Enhancement Association, and Texas Sea Grant volunteered to educate their members and contact them about the app and encouraged them to submit their catch using *iSnapper*.

Validation

Validation was performed at boat ramps by both TPWD surveyors and HRI staff by creeling as many boats as possible to intercept private recreational anglers using *iSnapper* after a

fishing trip. During the private recreational federal Red Snapper season (June 1 – June 10) 7 additional TPWD creel surveys were conducted with the intent to "recapture" as many *iSnapper* users as possible. Additionally, to augment creeling effort HRI staff conducted 5 surveys at high use marinas and boat ramps during the federal Red Snapper recreational season, and TPWD increased the number of random creel surveys throughout the 'high use' season (May 15 – November 20, 2015) from 764 in 2014 to 832 in 2015. Despite these targeted creels at high use sites, the anglers were still randomly intercepted, because interviewers did not know if any *iSnapper* trips had been started or submitted prior to the creel survey. During the interviews, one angler (typically the captain or designee) from the boat was asked how many Red Snapper were harvested, the number of anglers on the boat, depth fished, and if they had reported their catch using *iSnapper*. The accuracy of data submitted with *iSnapper* were validated by cross-referencing the creel surveys using vessel registration numbers to determine if their reported catch was the same as what was recorded dock-side. Certainly, by maximizing the numbers of validations that could be performed, the most accurate catch estimates could be determined. Anglers that were encountered not using the app were also surveyed, and they were informed about *iSnapper*, the value of using it, and were highly encouraged to download and use it for the duration of the federal and state Red Snapper seasons.

Catch Estimation

The traditional method for estimating recreational catch for most species and locations uses two complementary surveys of anglers, one to measure "effort" (number of fishing trips) done by phone or mail, and one to measure mean catch per trip, done face-to-face with dockside interviews. Use of electronic reporting allows effort estimates to be reported by the anglers on the day when the fishing actually took place, reducing problems with inaccurate estimates due to recall bias. However, using this data requires a validation process to monitor how accurate the reporting is. Anglers were encouraged to submit their trip data prior to arriving back in case they were intercepted by TPWD or HRI at the dock to prevent any bias and ensure independence in the self-reported data and validation process. With both the self-reported data and the validation, the population and sample data can be broken down into four categories (Figure 3) to calculate the number of trips and Red Snapper harvested. All of the categories, aside from the 'not reported or creeled', are used in a new estimator developed specifically for this project to

calculate the reporting and error rates to estimate the total Red Snapper harvest for private recreational anglers using self-reported data in 2015. The new estimator had to be developed since this type of data has yet to be included in catch and effort estimates. To calculate the total harvest or total number of anglers, the following equation was used:

$$\hat{t}_{y2} = t_{y^*} + \frac{n_1}{\hat{n}_1}(\hat{t}_y - \hat{t}_{y^*}) = t_{y^*} + n_1\hat{\bar{\delta}}$$

where $\hat{\bar{\delta}}$ is an estimator of $\bar{\delta} = (t_y - t_{y^*})/n_1$ which is the total population underreport averaged over the units in the reporting domain (i.e. the *iSnapper* reports). In the formula, t_{y^*} is the reported removals of Red Snapper (or reported number of anglers) based on the *iSnapper* app. n_1 is the number of vessel trips which reported their Red Snapper catch using *iSnapper*. $\hat{t}_y$ and $\hat{t}_{y^*}$ are the estimated number of Red Snapper catch (or number of anglers) of the whole population and the reporting domain, estimated from the validation sample only. While the derivation of the estimator is beyond the scope of this report please see Liu et al. (*In review*) for details.

		Sample Validated	
		Yes	No
Reported	Yes	Reported and validated	Reported, not creeled
	No	Not reported, creeled	Not reported or creeled

Figure 3. Illustration of the population and sample data.

Registration

      Anglers were able to download *iSnapper* at the App store (iOS) and Google Play (Android). Once downloaded, the first step in the data submission process involved anglers registering to set-up their *iSnapper* account (Figure 1A). At registration, participants provided their vessel registration numbers, giving a unique identifier critical for validation. Also, contact information was collected to allow administrators to contact anglers to resolve any observed errors. Once registered, the angler was able to immediately enter and submit their catch information from fishing trips. The process to submit a trip involved 3 simple steps (Figure 3). All of these steps could be done in less than five minutes, and typically within two minutes depending on the number of different species caught during the trip. Steps:

(1) Open the app and provide the date, time, marina/boat ramp the boat was launching

from, and the number of anglers;

(2) Fill in the catch data by selecting the species caught and entering number of fish

harvested and released; and

(3) End the trip by selecting a general fishing location on a map and the primary depth

fished for the trip and submitting.

There were several features that made the process easy, streamlined, and as user friendly as possible. For example, the date and time was automatically populated for the current time both when starting a new trip and closing a trip, but could be adjusted if the angler forgot to create a trip before leaving the dock. Additionally, when anglers harvested Red Snapper the app divided the catch into two categories: fish harvested in state waters and fish harvested in federal waters. Additionally, Red Snapper anglers were required to report the primary fishing depth on the catch screen. All species commonly captured throughout the Gulf of Mexico were included in the app, allowing anglers to submit their entire catch not only Red Snapper. Once the trip was finalized and submitted anglers could not edit nor delete their entry in the app or on the webportal. The only way to change trip information was to email HRI and have one of the researchers log in and adjust the trip. This was very important because to calculate an accurate error estimate, we compared the number of fish reported to the number of fish counted during dockside interviews. If anglers were capable of changing their catch information after submission, calculating the error rate would not be valid because anglers would have the ability to change the number of fish submitted on *iSnapper* if they were interviewed at the boat ramps by TPWD or HRI staff. Finally, all required app updates were "pushed" the user's phone as needed.
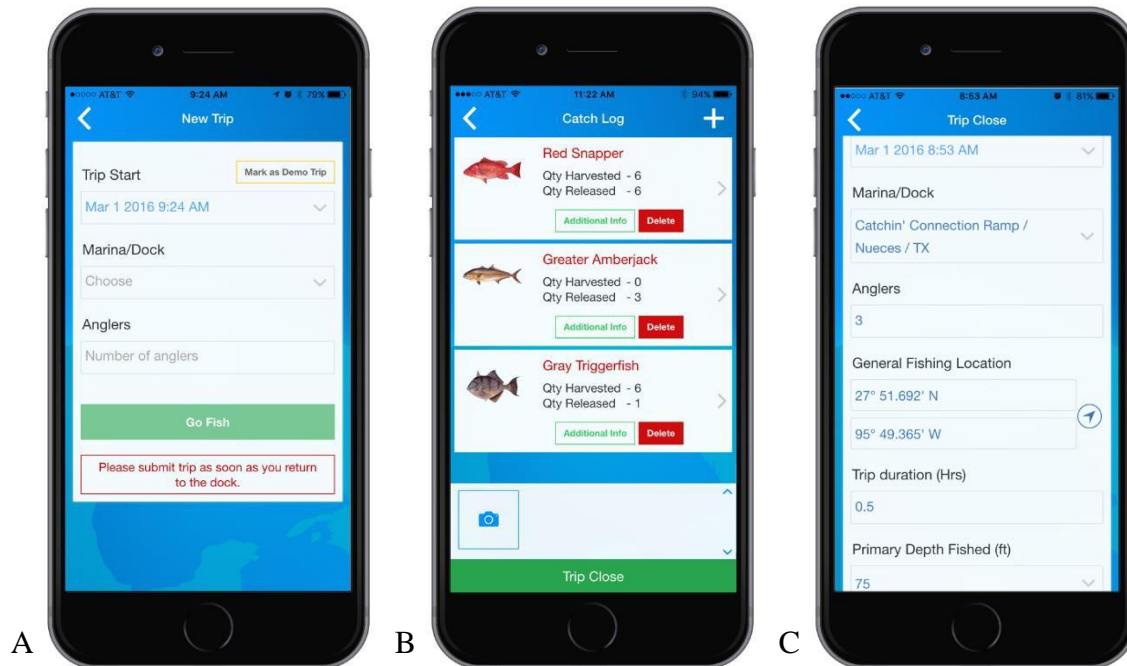
Figure 4. Screenshots of the new trip screen (A), catch log (B), and trip close screen (C).

Socioeconomics Survey

        While the previous three steps were required of all trips, there were other optional features that anglers could choose to enter. One of the features that proved to be very beneficial is the availability to collect additional socioeconomic information. The socioeconomic survey was a separate optional feature in the app and available on the home screen. Questions in the survey were similar to those used in the previous version of *iSnapper*; however, after receiving feedback from NOAA, we included additional questions to get more refined information regarding the cost of trips and distances traveled (Table 1). Even with these additions, the survey was brief and took less than five minutes.

Table 1. Socioeconomic questions included in *iSnapper*.

How many people in total, including yourself, live in your household? Please include those people who fish and who don't fish.
How many people in your household, including children and adults, have been recreational saltwater fishing in the last 12 months anywhere in the Gulf of Mexico region including inshore and offshore?
How many days did you spend saltwater fishing in the last 12 months?
How many of these days were spent offshore?
If this fishing trip is part of a longer trip in which you will spend at least one night away from your permanent residence, how many days will this trip last?
What is your primary and secondary (if applicable) zip code? (Enter zip codes separated by comma Ex: 12345,12346)
Gender
What is the total distance traveled by boat during this trip? (Miles)
Do you keep your boat at a marina or trailered?
What is the estimated bait and tackle expenses for this trip?
What is the horsepower of your boat?
What is the estimated fuel consumption used for this trip? (Gallons)
Which of the following best describes your household's annual income, before taxes? (US$)

For-Hire provision

Given the successful *iSnapper* pilot study in the for-hire sector and groundswell of interest by others, many groups routinely inquired as to the availability of its use. Thus, we redesigned *iSnapper* to include fields specifically for the for-hire captains so they could continue to submit trips, and the registration process enabled us to distinguish between private and for-hire trips. If a user selected the for-hire option during registration, state and/or federal permit numbers were required to complete the process. For-hire reporting followed the same format as with private anglers, and these trips were also validated at boat ramps, but for the majority of the analyses were not included due to the small number of for-hire trips reported.

V. Findings

Development and implementation of iSnapper as a data collection app:

The adaptation of *iSnapper* from a mobile application targeting for-hire captains to one that could be universally used by all recreational anglers was very successful. Since the release on May 15, 2015 the app was downloaded on 945 different devices through the end of 2015. The majority of the users (71%, 672 downloads) were operating a device with iOS (Apple®) platform, the remainder were Android-based users. A total of 393 individuals registered to use the app, with 199 users providing valid vessel registration numbers. During the initial development stages, the Windows® platform was an appealing operating systems, and we had anticipated high number of users. However, options for app development and the subsequent phase out of this platform by most developers lead to little interest, and we delayed implementing this platform to focus on the other two more popular formats. Moreover, with only 3% of all cell phone users listing Windows® as their phone type (Pew Research Center 2015), and that number rapidly declining, we do not recommend development of this platform for future data collection.

During the 10 day Federal Red Snapper season (June 1 – 10, 2015) there were 171 trips submitted using the app or the online web portal, with 163 trips from Texas private recreational anglers (Table 2). Red Snapper was the most dominant species captured, with all trips reporting a harvest of at least one Red Snapper. Other species commonly captured were King Mackerel (*Scomberomorus cavalla*), Cobia (*Rachycentron canadum*), and Dolphinfish (*Coryphaena hippurus*) (Table 3). A total of 2,012 fish were harvested during the federal season, with 75.5% of the harvested fish being Red Snapper. The next most prominent species harvested were Dolphinfish, King Mackerel, Vermilion Snapper (*Rhomboplites aurorubens*), and Blackfin Tuna (*Thunnus atlanticus*). Most trips (private and for-hire) using *iSnapper* were located within the continental shelf, generally within 100 nm offshore Texas (Figure 4A). Most vessels harvested 7 Red Snapper from their selected fishing locations, while some harvested 25 – 56 Red Snapper in these general areas throughout the season (Figure 4B). Despite a federal bag limit of 2 Red Snapper per angler, anglers were able to keep a maximum of 4 fish if 2 were from state waters. To calculate the estimated Red Snapper harvest the average length of fish recorded by TPWD was converted using the TPWD length/weight conversion chart (http://txmarspecies.tamug.edu/length-weight.cfm) and multiplying the weight by the total number of fish harvested. An additional 22 trips were started by Texas anglers during the federal season, but not completed. Despite including a feature to alert anglers if they had a trip open

longer than 24 hours, as well as reaching out to these anglers via email on multiple occasions, these trips were never submitted.

Although it was an abbreviated 10-day season, the weather conditions were optimal for offshore fishing. Light winds and small seas enabled most vessels to get out to fish federal waters (> 9 nautical miles), especially for some of the smaller (< 25') boats. The National Weather Service issues small craft advisories starting at wind speeds greater than 12.9 m/s. Average wind speeds throughout the federal season were never greater than 4.6 m/s and average wave height did not exceed 0.7 m (Table 2). With the conditions being relatively similar throughout the season, we were able to use the creel and app data to determine what days of the week corresponded with increased angler activity during the limited season. A majority (60%) of anglers fishing for Red Snapper went out on one of three days during the season: opening day (Monday), or the following Friday and Saturday (Figure 5). Not surprisingly, the day with the highest fishing pressure (Saturday) corresponded to the highest estimated daily harvest of 5,314 lbs.

Table 2. Number of self-reported trips using *iSnapper* from private recreational anglers in Texas during the federal Red Snapper season (June 1st - June 10th). Trips refers to the number of users that submitted fish captured during the season. Anglers includes all individuals on the boat that were targeting Red Snapper for at least a portion of their trip. Total released is the number of Red Snapper captured in either state or federal waters but discarded either due to size or bag limits. Harvested state is the number of Red Snapper harvested from state waters. Harvested federal is the number of Red Snapper harvested from federal waters. Daily harvest is the combined number of Red Snapper harvested from both state and federal waters. The asterisk (*) indicates what would be considered the weekend for a typical Red Snapper angler (Friday – Sunday).

Day	Trips	Anglers	Total Released	Harvested State	Harvested Federal	Daily Harvest	Average Wind speed (m/s) +/- SE	Average Wave height (m)
6/1 (Mon)	23	84	191	22	178	200	2.4 +/- 0.11	0.4 +/- 0.02
6/2 (Tue)	22	80	272	40	155	195	1.9 +/- 0.18	0.3 +/- 0.01
6/3 (Wed)	17	55	300	11	97	108	3.6 +/- 0.19	0.3 +/- 0.01
6/4 (Thu)	11	37	230	17	74	91	4.6 +/- 0.16	0.7 +/- 0.02
6/5 (Fri)*	23	105	259	24	206	230	4.2 +/- 0.21	0.4 +/- 0.02
6/6 (Sat)*	27	124	309	62	227	289	2.7 +/- 0.25	0.4 +/- 0.01
6/7 (Sun)*	19	89	148	25	174	199	4.0 +/- 0.25	0.4 +/- 0.01
6/8 (Mon)	10	40	115	12	79	91	4.1 +/- 0.28	0.5 +/- 0.02
6/9 (Tue)	7	30	96	10	60	70	3.2 +/- 0.17	0.4 +/- 0.02
6/10 (Wed)	4	19	20	8	38	46	4.2 +/- 0.22	0.5 +/- 0.02
Total	163	663	1940	231	1288	1519	3.5 +/- 0.08	0.4 +/- 0.006

Table 3. Summary of the species captured and released as reported using *iSnapper* by private recreational anglers during the Red Snapper federal season (June 1 – June 10). Number captured includes the combined number of fish harvested and released. An asterisk (*) next to a species name indicates the species is considered a bait fish. A horizontal dash (-) in the discard rate column indicates all fish captured were harvested. Number of anglers is not mutually exclusive by species, since several species are typically caught during one trip.

Species	Number Captured	Percent of Total Capture	Number Harvested	Discard Rate	Number Released	Number of Anglers
Red Snapper	3459	82.0%	1519	56.1%	1940	663
King Mackerel	139	2.4%	85	38.8%	54	148
Dolphinfish	119	1.0%	98	17.6%	21	99
Blue Runner*	57	0.7%	42	26.3%	15	21
Cobia	50	0.9%	30	40.0%	20	115
Gulf Menhaden*	50	< 0.1%	50	-	0	2
Blackfin Tuna	48	0.5%	37	22.9%	11	20
Greater Amberjack	42	1.7%	4	90.5%	38	57
Vermilion Snapper	42	0.1%	40	4.8%	2	34
Great Barracuda	39	1.5%	5	87.2%	34	18
Atlantic Sharpnose Shark	23	0.8%	5	78.3%	18	14
Gray Triggerfish	18	0.6%	4	77.8%	14	30
Golden Tilefish	15	< 0.1%	15	-	0	18
Atlantic Spadefish	14	0.2%	10	28.6%	4	10
Lane Snapper	10	< 0.1%	9	10.0%	1	17
Crevalle Jack	9	0.3%	2	77.8%	7	14
Almaco Jack	7	0.1%	5	28.6%	2	8
Tripletail	7	< 0.1%	6	14.3%	1	16
Rainbow Runner	6	0.1%	4	33.3%	2	9
Rock Hind	6	< 0.1%	6	-	0	9
Bermuda Chub	5	0.1%	2	60.0%	3	7
Gray Snapper	5	< 0.1%	4	20.0%	1	17
Little Tunny	5	< 0.1%	5	-	0	10
Remora	5	0.1%	2	60.0%	3	11
Bonito	4	0.1%	2	50.0%	2	10
Blacktip Shark	3	< 0.1%	2	33.3%	1	8
Sand Seatrout	3	< 0.1%	3	-	0	6
Scamp	3	< 0.1%	2	33.3%	1	10
Spanish Mackerel	3	< 0.1%	3	-	0	6
Atlantic Bonito	2	< 0.1%	1	50.0%	1	7
Dog Snapper	2	< 0.1%	2	-	0	4
Lesser Amberjack	2	0.1%	0	100.0%	2	4
Spotted Seatrout	2	< 0.1%	1	50.0%	1	2

| Species	Number Captured	Percent of Total Capture	Number Harvested	Discard Rate	Number Released	Number of Anglers
Wahoo	2	< 0.1%	1	50.0%	1	11
Yellowfin Tuna	2	< 0.1%	2	-	0	4
Blue Marlin	1	< 0.1%	0	100.0%	1	4
Bull Shark	1	< 0.1%	0	100.0%	1	5
Cubera Snapper	1	< 0.1%	1	-	0	4
Gag Grouper	1	< 0.1%	0	100.0%	1	6
Great Hammerhead Shark	1	< 0.1%	0	100.0%	1	3
Horse-eye Jack	1	< 0.1%	1	-	0	3
Others	1	< 0.1%	0	100.0%	1	5
Sailfish	1	< 0.1%	0	100.0%	1	5
Sandbar Shark	1	< 0.1%	0	100.0%	1	6
Scalloped Hammerhead	1	< 0.1%	0	100.0%	1	4
Warsaw Grouper	1	< 0.1%	1	-	0	4
Yellowedge grouper	1	< 0.1%	1	-	0	4
Total	4220	100%	2012	52.3%	2208	1492

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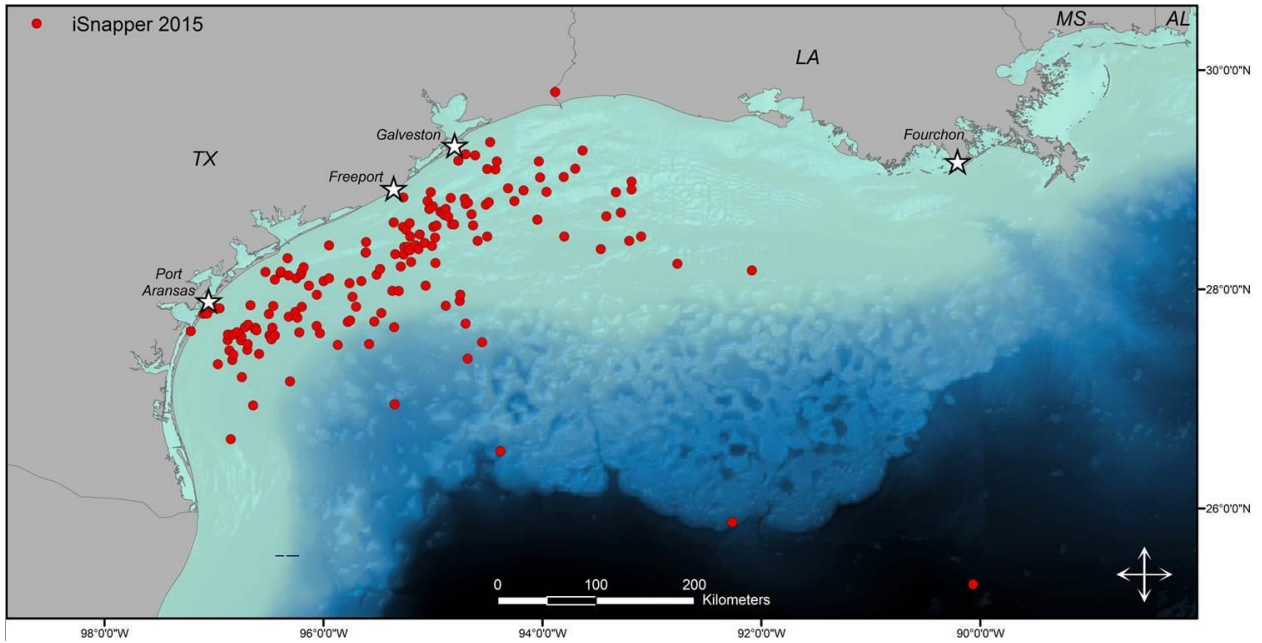
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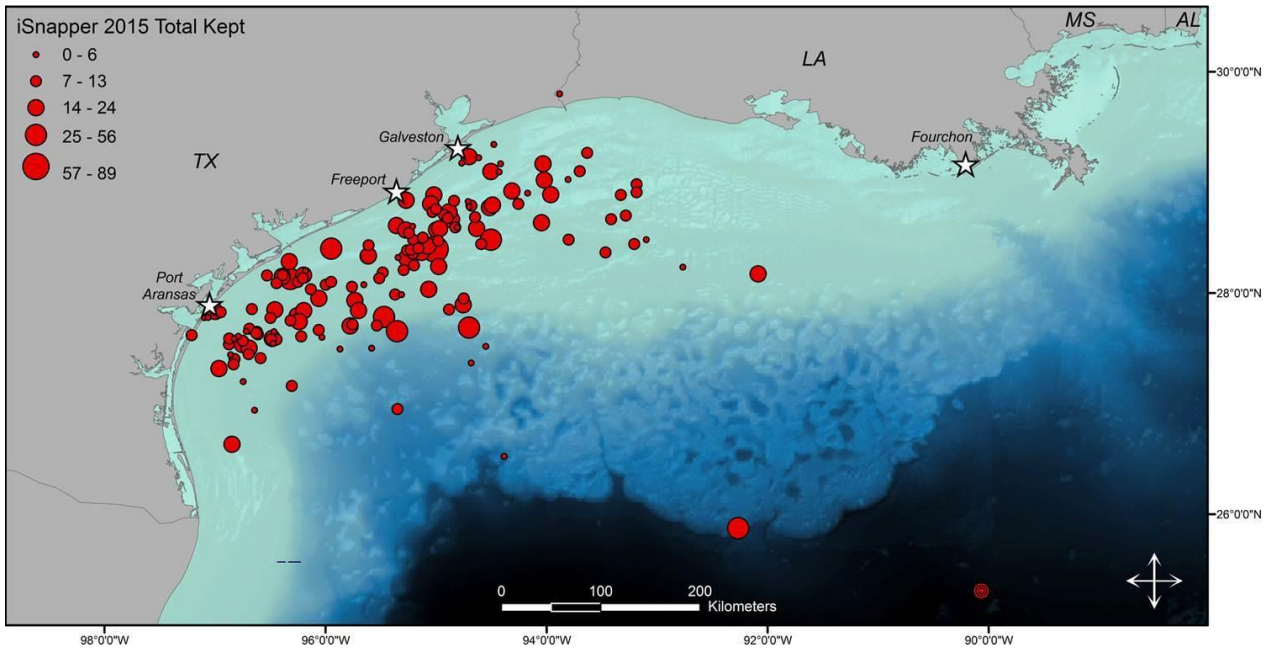
Figure 5. Approximate fishing locations (A) and total harvest by location (B) for *iSnapper* users during the 2015 Red Snapper season (June 1 – June 10). Locations on or outside of the continental shelf are likely errant entries, with the site on the shelf edge being the default location when the map loads on the app.

The majority of Red Snapper were caught at depths of 40 m or less (52.4%), with the most common reported depth of capture between 31 – 40 m (1,042 caught, 31.6%, Table 4). The overall estimated discard rate for Red Snapper was 56.1%, with the highest rate of 74.3% occurring at depths between 21 – 30 m. A total of eight trips did not report their fishing depth, which accounts for the 100 Red Snapper released at unknown depths. The depth range where most fish were retained occurred between 71 – 80 m, although there were relatively few (n = 68) Red Snapper captured at these depths.

Table 4. Depth of capture for Red Snapper during the federal season (June 1 - 10) as reported using *iSnapper* by private recreational anglers in Texas. The discard rate by depth was calculated by dividing the number released by the total number captured. The overall discard rate was calculated by dividing the total number released by the total number captured. Unknown depth refers to trips where a depth of 0 ft was reported in the app.

Depth (m)	Number Released	Number Harvested	Discard Rate
1 - 10	10	8	55.6%
11 - 20	48	91	34.5%
21 - 30	399	138	74.3%
31 - 40	611	431	58.6%
41 - 50	596	600	49.8%
51 - 60	0	0	0.0%
61 - 70	112	82	57.7%
71 - 80	15	53	22.1%
81 - 90	0	0	0.0%
91+	49	67	42.2%
Unknown	100	49	67.1%
Total	1940	1519	56.1%

Validation of self-reported data:

During the 10 day federal season a total of 1,018 private recreational Red Snapper anglers were encountered at Texas boat ramps. Not all of these anglers were "unique" individuals, with some anglers going out on multiple days. These anglers represented 259 trips and harvested 2,268 Red Snapper (Table 5). Of the 163 trips submitted using *iSnapper*, 18 were interviewed at the boat ramp, generating an 11% trip validation rate and an overall reporting rate of 4.1% (see Appendix 1 for additional details on calculations). Two trips reported a higher number of fish harvested than

were recorded during the creel survey and one trip reported fewer fish harvested, for a total reporting error of +5.1%. Most of the trips encountered at boat ramps occurred on June 5 and June 6 (Friday and Saturday; Figure 5). Close to half (45.2%) of the total Red Snapper harvest was recorded during these two days. While the app was created with the capability of capturing the trip start and end times, initially it did not capture the date and time when the trip was actually submitted. Unfortunately, it is difficult to know if anglers submitted trips prior to being interviewed. Following the federal season, we did update the app to begin collecting submission date and time, but there were not enough trips validated after the correction to calculate an adjusted error rate. However, we feel the error rate is fairly accurate as not every trip had 100% reporting accuracy (Table 5), as one would expect if they submitted their data after being interviewed.

Table 5. Creel survey summary of private recreational anglers intercepted during the federal Red Snapper season (June 1 - June 10) by TPWD and HRI scientists. The harvest reported by all *iSnapper* users is included for ease of comparison between the app and creel surveys. Validated trips were anglers that submitted a trip using the app and were also interviewed at their landing location. Reporting accuracy rate for validated trips was calculated by dividing the app harvest by the creel reported harvest and multiplying by 100.

| Day	Boat Trips	Anglers	Creel Harvest	*iSnapper* Harvest	Validated Trips	Reporting Accuracy Rate
6/1/2015 (Mon)	33	107	278	200	2	100%
6/2/2015 (Tue)	13	42	113	195	2	100%
6/3/2015 (Wed)	22	87	206	108	0	-
6/4/2015 (Thu)	24	80	210	91	2	63%
6/5/2015 (Fri)	63	246	581	230	5	96%
6/6/2015 (Sat)	78	307	643	289	6	84%
6/7/2015 (Sun)	11	45	108	199	0	-
6/8/2015 (Mon)	7	33	65	91	1	100%
6/9/2015 (Tue)	5	13	38	70	0	-
6/10/2015 (Wed)	3	9	26	46	0	-
Total	259	969	2268	1519	18	94.9%
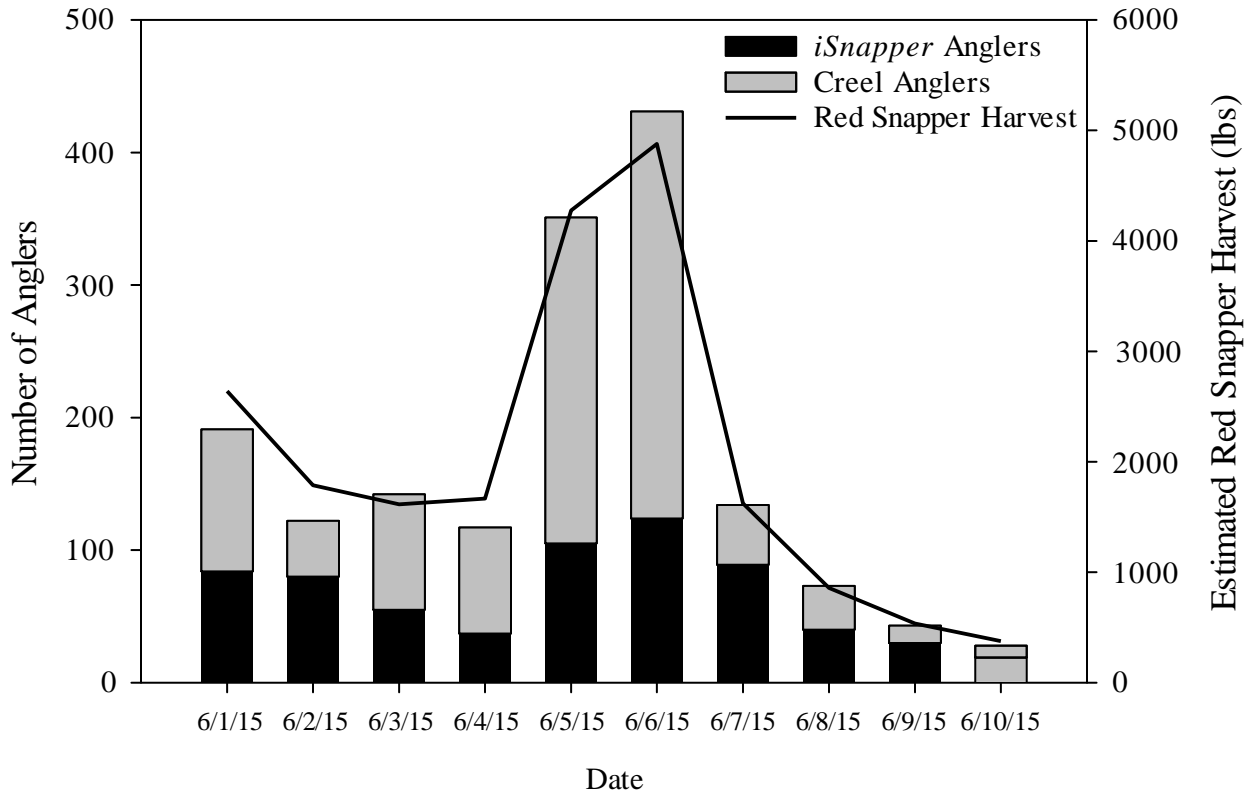
Figure 6. Total number of Red Snapper anglers reporting using *iSnapper* (black bar) or intercepted at boat ramps (gray bar) fishing for Red Snapper during the federal season. Estimated Red Snapper harvest was calculated by taking the average length of fish recorded by TPWD, converting the length to an estimated weight using the TPWD length/weight conversion chart (http://txmarspecies.tamug.edu/length-weight.cfm) and by multiplying that weight with the total number of fish harvested.

After the federal season, anglers were encouraged to continue using *iSnapper* to report their state catch. The TPWD also continued their increased creel surveys to encounter Red Snapper anglers and validate additional trips. From June 11th until the last reported creel with Red Snapper on November 4th an additional 165 boats were interviewed with 1,734 Red Snapper harvested. Only 38 trips harvesting a total of 433 Red Snapper were reported using *iSnapper*, with one boat validated during this time and it was a charter for-hire vessel. The number of Red Snapper harvested was accurate (20), although with the app they reported one less angler than what was recorded by TPWD.

iSnapper total Red Snapper harvest estimate:

Texas is unique in that the harvest of Red Snapper occurs all year in state waters. Using the reporting rate and error estimates from the federal season, along with creel data provided by TPWD for the entire year, the estimated total number of Red Snapper captured by Texas private recreational anglers was 58,251 fish (SE = ±25,344; see Appendix 1 for SE calculations). Using the reporting rates we calculated the total number of Red Snapper angler trips was 23,358 (SE = ± 6,660). To provide a landings estimate for private recreational anglers, the average size of fish captured from both federal and state waters was calculated and then the weight was estimated using a length/weight conversion website provided by TPWD (http://txmarspecies.tamug.edu/length-weight.cfm). In Federal waters the Red Snapper mean length harvested was 22.1 inches and the mean estimated weight harvested was 5.63 lbs. In State waters the mean size of 20.2 inches, which is approximately 4.25 lbs. Using the harvest estimates and average weights, the estimated landings of Red Snapper for Texas private anglers in 2015 was 277,752 lbs (Table 6).

Table 6. Total Red Snapper harvest estimates for 2015 using data from *iSnapper* and TPWD data. Angler-trips is the estimated total number of anglers fishing, which includes anglers fishing for multiple days.

Method	Number Harvested	Weight (lbs)	Angler-Trips
iSnapper	58,251 (± 25,344 SE)	277,752	23,358
TPWD	32,062 (± 4,409 SE)	153,525	11,154

Socioeconomic data:

Following the launch of *iSnapper* on May 11th, a total of 100 socioeconomic surveys were completed by 95 unique respondents. Most of these entries occurred after the opening of the federal season, with the most single day entries occurring on June 4th (Figure 6). A total of 98% of respondents were men and 93% of respondents were Texas residents (Figure 7). On average, participants went saltwater fishing 35 days over the past 12 months, with 14 days of those spent offshore. Most (70%) participants also trailered their boats. In terms of household income of Red Snapper anglers, approximately 25% had an annual household income of over $200,000 and approximately 61% had incomes over $100,000 (Figure 8). The average distance these anglers traveled per trip was 89.3 miles (± 7.09 SE), using an estimated 82 gallons of fuel (± 12.0 SE). The average cost of bait and tackle for the trip was $197 (± 34.22 SE).

Number of entries

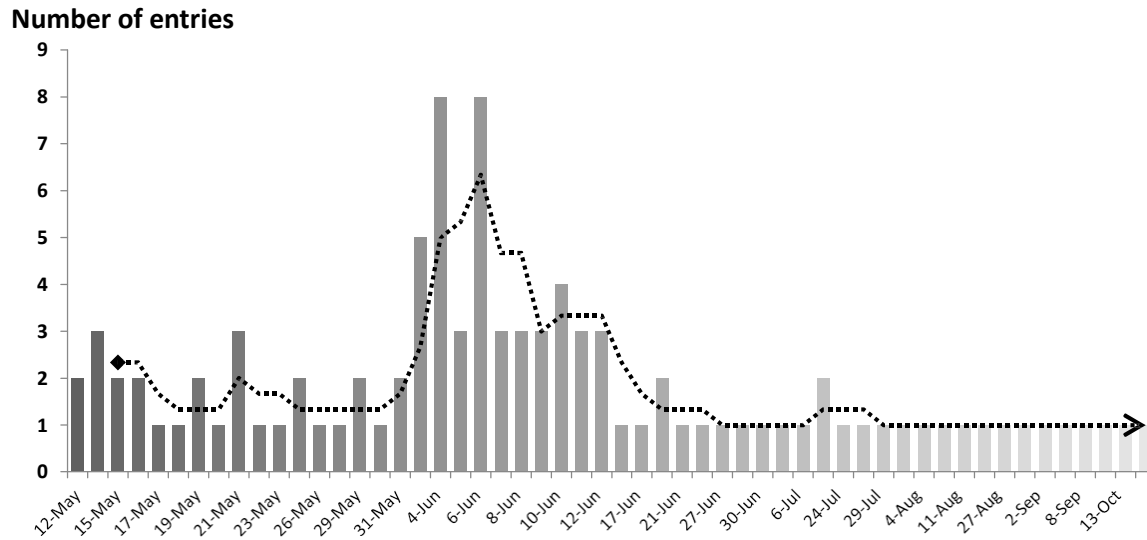**Figure 7.** Number of socioeconomic surveys submitted each day following the release of *iSnapper*. The dotted line indicates the two day lag average, where the number of entries from the previous two days were averaged.
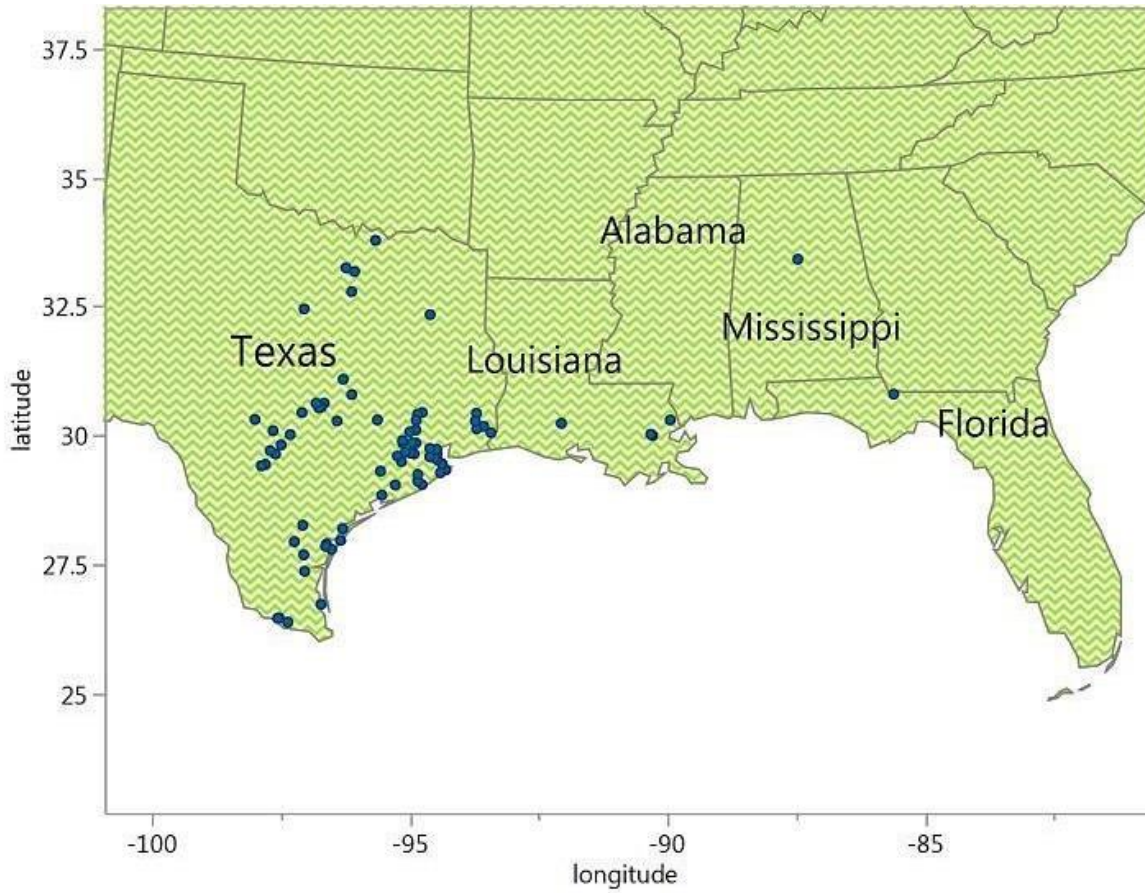
Figure 8. The primary residence locations based on zip code for anglers submitting a socioeconomic survey using *iSnapper*.
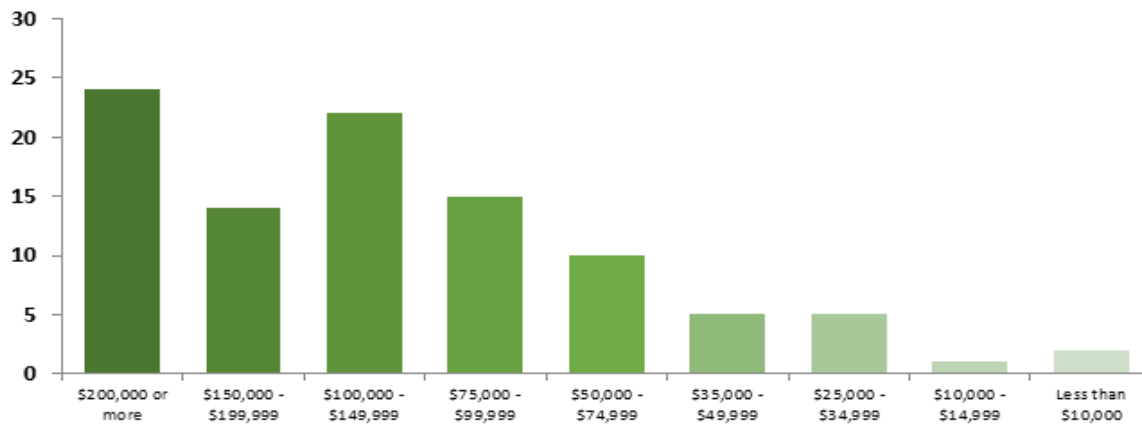

Figure 9. The average annual household income for respondents using *iSnapper*.

iSnapper in the for-hire fishery and use in Exempted Fishing Permits:

During development of the initial proposal, there were several Exempted Fishing Permits under consideration in the for-hire sector. *iSnapper* was proposed as an ideal data collection tool for these programs; however, none of these materialized to test the viability in these programs. Nevertheless, it still represented a valuable tool for data collection in the for-hire sectors, and *iSnapper v1.0* was very successful and popular. In 2015 the for-hire captains had a 44 day season where they could harvest Red Snapper in federally managed waters from June 1st until July 15th. Curiously, there were few trips reported from this sector using this pilot - *iSnapper v2.0*, and this low reporting did not allow for catch estimates to be performed for this sector. Six for-hire captains submitted seven trips during their season and harvested a total of 76 Red Snapper, 25 Dolphinfish, 6 King Mackerel, 1 Warsaw Grouper, and 1 Yellowedge Grouper. Six additional state water trips were submitted by one user who harvested a total of 128 Red Snapper and did not report any other species captured or harvested. In terms of discards, these captains reported no Red Snapper released during the 44 day season in federal waters. Whereas when fishing in state waters, a total of 45 were released. Despite having so few trips reported, two of the for-hire trips were validated with creel surveys. Including these data with the validations from the private recreational data decreased the overall error rate from 5.1% to 4.1%. Nevertheless, these did not represent enough sample size to make valid harvest estimates for this sector.

VI. Discussion

This project demonstrates that smart device apps can successfully and efficiently be used as a data collection tool for private recreational anglers. The near-real time data collected can greatly aid in the timeliness of the data generated, which is especially important in the Red Snapper federal fishery which was only open for 10 days in 2015. This real-time data collection allows for fishery managers to make more accurate estimates of the total harvest as well as better determine the fishing effort. Collecting fisheries-dependent data is certainly key for effective fisheries management, and this process is typically characterized as being labor intensive, expensive, and often has relatively long time delays to produce final products. These inherent characteristics do not always mesh with certain management measures that create very short seasons, or afford the ability for managers to assess catch in relation to annual catch targets during the season, but often occur well-beyond the "projected" season closure. This makes adaptive management difficult and prone to

risk if these targets are exceeded before the catch can be calculated, and it also contributes to inefficiencies in management. These issues could not be more apparent than in private recreational fisheries. Many of these problems have the potential to be allayed by supplementing (or even validating) traditional fishery dependent surveys with data from smart device application technology and data collection. For example, these devices capture portions of the fishery that are likely missed by traditional creel surveys (e.g., private dock and marinas) and collected a host of data that traditional surveys do not. These devices also allow for collection of spatial/locational fishing effort, refined effort estimates, discard rates, depth fished, socioeconomic data and a host of other parameters. Much of these data are collected in a seamless user friendly fashion that is often automated. Overall, this study clearly demonstrates the high potential of using electronic reporting apps to aid in the private recreational fishing data collection and provide traditional and new forms of data in a very efficient and timely manner.

The need for more robust, accurate, and timely data from the private recreational sector is making the use of smart devices as data reporting tools more of a reality. These devices allow anglers to self-report their catch and effort data without having to rely on being intercepted and interviewed by state agencies. It also enables anglers that have private docks to report their catch, which previously was not possible and often had to be estimated, since there is not a point of encounter such as at boat ramps. With high private angler reporting rates, managers will be able to more precisely estimate total harvest that likely would benefit the access to the fishery. Knowing how many private anglers need to report each year can be estimated, but greatly depends on what the desired or acceptable standard error rate is, which would need to be set by State and Federal managers. With high precision in the total harvest, the ability for these apps to collect near real-time data can be used to make in-season adjustments to season length based on the current harvest. This is particularly important for a species such as Red Snapper that has such a short season, where traditionally the harvest could not be estimated during the season, because it took months of data entry and analysis that were processed only after it fishing had ended. While the user-submitted data is immediately available through the web portal, harvest estimates can only be calculated once the creel data has been entered and trips have been validated. A reasonable time frame to calculate a final harvest for the federal Red Snapper season is three weeks following the close of the season; however, "preliminary" estimates could be made sooner. The three-week time frame is due to the time it takes for TPWD to process creel data for validation. This amount of time allows for the

creel data to be entered, trips validated, and then estimating the harvest, which is generally much faster than traditional methods.

With the prevalence of smart phones and the relative low cost of creating an app (Stunz et al., in prep), this type of data collection has a large potential to greatly benefit managers. If designed properly, the apps can provide catch and effort data as well as supplementary information such as depth of capture and release condition at relatively low cost once developed. Depending on what questions fisheries managers seek to understand, the app can be created with additional features and options to address specific concerns about a fishery in a particular region or focus area. For example, in *iSnapper* we provided a section where anglers could describe the release method and condition of fish that were released. With these data, the post-release mortality could be calculated for species in the Gulf that experience significant barotrauma (Lutjanids, Serranids), which could then be incorporated in overall fishing mortality estimates or estimates of depth fished. As a practical example, it has been shown that Red Snapper survival is highest when fish are caught in shallower waters (< 30 m) during the cooler months and are released using either rapid recompression (descender devices) or venting tools (Drumhiller et al. 2014, Curtis et al. 2015). Currently, there are no estimates of what methods private recreational anglers commonly use to release Red Snapper. Since all of those key parameters are collected in *iSnapper* it would be possible to gauge if anglers are releasing fish that have been vented, are descending them using various devices, or are simply discarding them without any barotrauma treatment. This information would help estimate survival rates based on our current knowledge of the likelihood fish survive based on the depth and season captured, which ultimately would provide information for more accurate discard mortality calculations. In addition, since the app is publically available the potential to collect an expansive data set with relatively little effort would be invaluable to management agencies to better address barotrauma issues and how they impact fisheries. This is just one example of how ancillary data collected by these techniques go beyond traditional catch and effort estimates.

A key component of ensuring self-reported data are valid and of practical use in fisheries management is a strong validation process. Requiring users to provide their vessel registration numbers allowed scientists to compare trips submitted with the app reported data to dockside creel surveys to measure the accuracy of self-reported data. Partnering with TPWD proved to be an efficient way to validate self-reported data, since creel agents are already routinely interviewing

boats for their coast-wide biological assessments. Ideally to improve estimates and reduce variability, expanding creeling effort to maximize validations, particularly future directed creel survey in areas of high use, would allow for greater harvest estimate accuracy. For example, the number of boat ramps and marinas that have access to the Gulf are relatively limited in Texas. Out of the 258 boat ramps that are sampled by TPWD Coastal Fisheries, from 2011 – 2014 only 31 ramps recorded Red Snapper harvest, and even fewer (13) recorded Red Snapper landings for more than ten trips. Due to the short federal season, it would be feasible to increase the number of creel surveys done at these highly used ramps to increase the validation rate, making the data more reliable. In addition, with this type of 'mark and recapture' method, managers can determine *a priori* the number trips needing to be validated to obtain an ideal, or acceptable, standard error for their harvest estimate. Due to the high expense and time cost of creel surveys, knowing the minimum number of trips that must be validated to reach a certain standard error rate would improve efficiency while allowing accurate catch estimate calculations.

One of the unique aspects of this pilot was the ability to collect data from the entire recreational fishing universe and use that information to make harvest and effort estimates. This type of capture-recapture survey methodology allowed us to have a strong data validation component, while also ensuring a randomized sampling design. From the calculated reporting rate and the error estimates, we were able to estimate the total Red Snapper harvest for 2015, as well as the number of angler trips fishing for this species. Understanding how many private anglers are targeting Red Snapper is critically important, as it has been difficult for TPWD to estimate the total number of Red Snapper anglers due to the high number of Texas residences that have private docks. Certainly, this is assuming similar validation characteristics of private dock anglers as those using public areas. However, there is no indication there are systematic discrepancies here, but this would be an area to improve validation and estimates to calibrate "private" landings.

We calculated that the 2015 landings from *iSnapper* were 277,752 lbs compared to 153,525 lbs estimated by TPWD. Based on our validation studies, these appear to be reasonable estimates of the private recreational harvest for 2015, but they are also characterized by a high degree of error. This estimate is the first independent assessment from the traditional harvest methodology and represents only one data point. Clearly, more data collection would need to be performed to increase the confidence in this estimate. Thus, some caution should be taken when evaluating these data for any type of management advice. While the estimates are somewhat larger here, it was also not

unexpected, given the app likely captures a segment of the fishery not surveyed using the standard state methodology. There are several plausible explanations for this difference. The estimate was characterized by a high standard error rate, and the lower bounds of our estimate fall within TPWD estimates. Also, we collected data from anglers that might not have the opportunity to be interviewed by TPWD, particularly people that have a private dock or arrive back to the boat ramps after 6 pm, when the creel assignments end. Thus, *iSnapper* allows these anglers an opportunity to have their catch included in the state harvest estimates. Finally, the 10-day federal season was characterized by ideal fishing conditions. Ideal weather led to high fishing effort, and our observations showed at certain times the boats arriving at the dock could easily overwhelm a creeling location leading to an underestimate. Overall, greater user buy-in would translate into additional submitted trips decreasing the standard error and ultimately calculating a more accurate harvest and angler estimate, making the data more useful for fisheries managers.

The method of data validation proved to be valuable in more than just estimating the total harvest of Red Snapper from the Texas private recreational fishery. Because this study was a capture-recapture design, it allows for flexibility and prioritization when determining how best to sample the population of private recreational anglers. For example, if managers seek a specific reporting rate, they would be able to calculate the number of trips that need to be validated during creel surveys. Additionally, to minimize the standard error of a harvest estimate, managers could also determine how many anglers need to report their catch for their desired estimate. Another major benefit is that the actual number of private recreational anglers in the fishery does not need to be known beforehand. These characteristics and benefits of a capture-recapture design show the feasibility of collecting statistically sound self-reported data that can and should be used by state and federal managers.

While the reporting rate was acceptable, and we were able to generate confident estimates, we anticipated more trip submissions. This was especially the case given the perceived interest in the fishery and extensive outreach and advertising campaigns undertaken. We would expect the reporting rate to increase through time as anglers become more aware and familiar with the app. Moreover, given the nature of "recreational" fishing, many anglers may not be willing to go the extra effort to enter data on a voluntary basis, given this is an activity to escape from these sort of tasks. Thus, future efforts should seek to maximize awareness in the private recreational community and simplify and streamline data entry as much as possible to ensure an enjoyable experience that

anglers will want to return and enter trips. Even though we had a very high number of downloads, we attribute some of the low reporting due to the app being voluntary. For example, Alabama has had mandatory Red Snapper reporting since 2014. This program has had a higher reporting rate - approximately 25% of Alabama private recreational vessels reported their catch (Alabama Department of Conservation and Natural Resources 2015). Because 2015 was the first season *iSnapper* was used for private recreational data collection, our reporting rate of 4.1% is encouraging. We believe there will be far greater participation in the future since it appears as though a majority of anglers were simply not aware of the app, and most interviewed seemed very willing to report their catch. This problem could be resolved by building on the current momentum from 2015 and continued advertising to inform anglers about the premise behind *iSnapper* and why private recreational data collection is critical. Nevertheless, we were still able to generate viable estimates and confidence intervals around those catches. Clearly, from these examples voluntary or mandatory reporting still does not ensure the majority of anglers report, and future studies should focus on the trade-offs associated with mandatory versus voluntary reporting and how these different collection frames influence the estimates and associated errors.

In general, we discovered that using the app requires a behavioral change by private anglers outside of their normal routine. They have to start a trip using the app prior to leaving the dock and then also submit the trip once they return to port. It will take time for anglers to commit and remember to use *iSnapper* for every trip. Additionally, with the Red Snapper fishery being so contentious, there is often mistrust between the anglers and fisheries managers, which at least in discussion with some contributed to their unwillingness to provide fishery-dependent data. As is the case for any data collection endeavor rather it be in person or electronic, some anglers voiced opposition to any type of information transfer such as refusing creels, data entry, etc. Fortunately, the events were rare, and the capture-recapture statistical methodology is robust enough to account for these non-reports. Nevertheless, these findings point toward a need for additional outreach and education directed towards private recreational anglers and how reporting would benefit them, because generally we found most are unaware but willing to help and take what steps are necessary to provide better catch estimates.

iSnapper provides a convenient mechanism to collect socioeconomic data on the users of the resource. This allows managers to conduct equivalent socioeconomic 'monitoring' similar to standard bio-physical measurements instead of ad-hoc processes that are common whether it be

commercial (Clay et al., 2014) or recreational (Carter, 2015) estimates. Furthermore, the socioeconomic data is connected from the angler at the time of the activity rather than the individual having to recall expenditures and other activity several months later when contacted for a phone, mail, or online survey. While it is not a stratified random sampling of anglers, the convenient sampling can provide valuable data to identify emerging trends that may require additional study as well as coupling it with traditional survey data. Even with our limited sample size (n=95) this pilot study demonstrated that anglers would voluntarily offer information on expenditures, as well as other data, when not prompted in a formal survey. Assessments of economic impacts and effort in recreational fisheries can be enhanced by knowing the distance of trips taken, consumption of fuel, and expenditures on bait and tackle.

Despite redesigning the app to be more marketable to the private recreational fishing sector, *iSnapper* also collected data with similar data fields for the for-hire sector. However, we were very astonished that only six *iSnapper* users were for-hire charter captains, despite extensive outreach to this community, particularly for Texas. We attribute the low numbers to Amendment 40 passing, which separated the for-hire boats from the private recreational boats into two separate sectors. With this change the for-hire boats were strongly encouraged to adopt a reporting system similar to that of the commercial vessels. There is also ongoing pilot programs using vessel monitoring system (VMS). Other states were capturing the for-hire industry using their data collection program (e.g., Snapper Check in AL, and LACreel in LA) in their region. This may have led to confusion within the sector as to what reporting mechanism to use. Nevertheless, the current version of *iSnapper* was designed with a charter for-hire component and is readily available for use if desired.

VII. Conclusions and Recommendations for Improvements

Our data collection pilot study demonstrated that a smart device "apps" are viable fisheries management tools that effectively collect near real-time fisheries-dependent data from the recreational fishing sector. The app can also be customized to collect important and difficult to obtain data (e.g., discard and location information) that may be used to better estimate parameters such as fishing mortality. While this pilot was specifically targeting Red Snapper anglers, *iSnapper* has the potential to be used to help with management of other species, since all commonly caught species in the Gulf of Mexico are included in the app. The use of this new type of technology as a data collection tool has much potential when recreational anglers see the value in providing their

catch data. Due to the short federal Red Snapper season, data collection tools like *iSnapper* in collaboration with federal (i.e., MRIP) and state creel surveys can be used to improve current harvest estimates as well as collection of ancillary fisheries and socio-economic data. In general, we had very positive feedback from anglers, and continuing the momentum created from 2015 would be beneficial to state and federal managers and result in additional data.

After examining the results from this study there are several key items that would improve any future data collection efforts using *iSnapper* and some lessons learned during this pilot. The majority of the issues uncovered related to problems when collecting self-reported data from private anglers; however, many have the ability to be improved:

- Mandatory reporting of all anglers targeting Red Snapper may be a logical next step in obtaining a larger dataset from the app. While mandatory reporting does not guarantee that all anglers will report, there would likely be more trips submitted which would allow for a more robust data set and a reduction in variability in catch estimates; thus, helping with the accuracy of the total landings estimates for the season. Analysis of a voluntary versus mandatory program would be beneficial to assess the cost-benefit of each system. No changes would need to be implemented in the app for mandatory reporting. The only change would be to create an account for enforcement to log into so they can view current trips.

- Another unforeseen issue that occurred during this project was that in some circumstances users did not providing accurate vessel registration numbers. While users were required to provide a valid vessel format (ex. TX1234TX), cross referencing the numbers provided with an actual state registry list was not possible during this pilot. Ideally, the registration would be linked with TPWD Boater's Registration office and users would query the database using their name and address to select their boat during the *iSnapper* registration process. Being able to confirm the vessel registration prior to the angler entering data would be very beneficial as it would improve validation at the marina. In the current study the trips with false registration numbers were excluded from our validated process and contributed to a lower validation rate. With all registered users required to find and select their boat would ensure that every *iSnapper* user encountered at the ramps would become a validated trip.

- One of the most difficult aspects of conducting a voluntary study is user involvement. Despite an extensive outreach campaign by both TPWD and HRI, a majority of anglers interviewed were not aware of the app. When anglers were informed about *iSnapper*, some suggested it was unlikely that they were going to download and report their 2015 catch since the federal season was only 10 days and many only fished one or two days of the entire season. These anglers expressed they did not believe their one day of fishing would have any impact on the data or it would be worth reporting, despite understanding the need for better data. This lack of knowledge and limited season was likely a motivating factor influencing the number of trips submitted.

- Another challenge was having anglers change their behavior to use a smart device app. As with any type of behavioral change it takes time to get people actively participating and anglers typically have their own fishing routines. Introducing an extra step of starting a trip on the app before they leave the dock and then submitting their catch prior to getting back to the dock takes additional effort. Not only do users have to be willing to participate, but they also need to remember to use *iSnapper* when typically their phones are stored throughout the trip and not used until after they are back at the dock. Although the app is user friendly and a trip can be filled out in typically less than five minutes, it is still an extra step anglers are not accustomed to doing and have to make a concerted effort to complete.

- The feedback from anglers while encountered at boat ramps was encouraging. Many of them were hopeful that a new way to collect harvest data could be the answer to providing more accurate and robust data which could lend itself to allowing for an increase in the quota. In addition, all anglers that were asked to provide feedback regarding the app were impressed by the features and ease of use, which is promising when considering the potential for *iSnapper* for the 2016 Red Snapper season.

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