FEATURE

Assessing the Utility of a Smartphone App for Recreational Fishery Catch Data

Ryan P. Jiorle*
Fisheries and Aquatic Sciences, School of Forest Resources and Conservation, University of Florida, 7922 NW 71st St., Gainesville, FL 32653. E-mail: rpjiorle@gmail.com

Robert N. M. Ahrens and Micheal S. Allen
Fisheries and Aquatic Sciences, School of Forest Resources and Conservation, University of Florida, Gainesville, FL

*Current address for Ryan P. Jiorle: 2600 Washington Avenue, Third Floor, Newport News, VA 23607

Photo credit: FWC Fish and Wildlife Research Institute.

There is a need to improve the management of recreational fisheries, and some organizations have begun piloting and implementing opt-in, self-reporting smartphone and tablet apps to further that goal. We began the process of developing a methodology for assessing the utility of these apps for management by comparing mean catch/trip values of selected species between the Snook and Gamefish Foundation's iAngler app and the Marine Recreational Information Program survey. The iAngler data set is used almost exclusively in Florida and is characterized by high spatial variability. However, its catch rates for Common Snook *Centropomus undecimalis* (medians ranging from 0 to 2), Spotted Seatrout *Cynoscion nebulosus* (medians from 1 to 3), and Red Drum *Sciaenops ocellatus* (medians from 0 to 1) were similar to those provided by the Marine Recreational Information Program (medians ranging from 1 to 2, 1 to 4, and 0 to 3, respectively). Self-reporting programs often suffer from biases concerning angler avidity, drop-off, and lack of angler representativeness but have the ability to provide data where traditional methods cannot. If methods to correct such biases are developed, programs like iAngler have the potential to provide valuable catch rate data to fisheries managers.

Utilidad de aplicaciones en teléfonos inteligentes para colectar datos de captura en pesquerías recreativas

Existe una necesidad de mejorar el manejo de las pesquerías recreativas y algunas organizaciones han comenzado a manejar e implementar aplicaciones (apps) en tabletas y teléfonos inteligentes para "auto-reportar" información en pro de dicha necesidad. Se desarrolló una metodología que evalúa la utilidad de estas apps para el manejo, mediante una comparación de los valores de la captura/viaje promedio de ciertas especies entre la "iAngler app" utilizada por la Fundaciones Snook y Gamefish y el Programa de Prospección de Información Marina Recreativa (PIM). La base de datos iAngler se usa casi exclusivamente en Florida y se caracteriza por presentar una alta variabilidad espacial. Sin embargo, las tasas de captura del robalo blanco *Centropomus undecimalis* (medianas entre 0 y 2), la corvina pinta *Cynoscion nebulosus* (medianas entre 1 y 3) y la corvineta ocelada *Sciaenops ocellatus* (medianas entre 0 y 1) fueron similares a aquellos que produjo el PIM (medianas entre 1 y 2, 1 y 4 y 0 a 3, respectivamente). Los programas de auto-registro suelen sufrir de sesgos debidos a la avidez de los pescadores de barco, renuncia y falta de representatividad de los pescadores, pero tienen la habilidad de proporcionar datos que no pueden los métodos tradicionales. Si se desarrollan métodos para corregir tales sesgos, los programas como el iAngler tienen el potencial de proporcionar valiosos datos de captura a los manejadores de pesquerías.

Évaluation de l'utilité d'une application smartphone pour la capture de données de la pêche récréative

Il est nécessaire d'améliorer la gestion de la pêche récréative, et certaines organisations ont commencé le pilotage et l'implémentation d'applications d'adhésion et d'autodéclaration pour smartphones et tablettes pour faire avancer cet objectif. Nous avons commencé le processus d'élaboration d'une méthodologie d'évaluation de l'utilité de ces applications pour la gestion en comparant les valeurs moyennes des espèces sélectionnées entre l'application iAngler de la Snook and Gamefish Foundation et l'enquête du Marine Recreational Information Program. L'ensemble de données d'iAngler est utilisé presque exclusivement en Floride et se caractérise par une grande variabilité spatiale. Cependant, ses taux de capture du brochet de mer *Centropomus undecimalis* (médianes de 0 à 2), de l'acoupa pintade *Cynoscion nebulosus* (médianes de 1 à 3), et de l'ombrine ocelée *Sciaenops ocellatus* (médianes de 0 à 1) étaient semblables à ceux fournis par le Marine Recreational Information Program (médianes allant de 1 à 2, 1 à 4, et de 0 à 3, respectivement). Les programmes d'autodéclaration souffrent souvent de biais concernant l'avidité des pêcheurs, de problème de connectivité et du manque de représentativité du pêcheur, mais ont la capacité de fournir des données là où les méthodes traditionnelles ne le peuvent pas. Si les méthodes pour corriger ces biais sont développées, des programmes comme iAngler ont le potentiel de fournir des données précieuses sur les taux de capture aux gestionnaires des pêches.

INTRODUCTION

The economic importance of recreational fishing in the United States engenders the need to adequately assess stocks and manage for sustainability. The conclusion that recreational fisheries have the potential to cause overfishing (Post et al. 2002; Coleman et al. 2004) means that, by law, this sector must be included in a fisheries management plan under the Magnuson-Stevens Fishery Conservation and Management Act, if the fishery exists in federal waters (generally, beyond three miles from shore). In the Gulf of Mexico, recreational landings have often exceeded commercial landings for high-profile stocks such as Red Snapper *Lutjanus campechanus* (Coleman et al. 2004) and Gag *Mycteroperca microlepis* (NOAA 2012). Other stocks, such as Common Snook *Centropomus undecimalis* and Red Drum *Sciaenops ocellatus*, no longer have a commercial sector, so stock assessments require data from recreational fisheries. In order to ensure long-term sustainability of such stocks, scientists and managers need a process for gathering reliable information from recreational anglers.

Sampling and assessing the marine recreational sector is challenging. Recreational fisheries are diverse and dispersed, and monitoring on this scale becomes costly (Pereira and Hansen 2003). Both state and federal programs seek to quantify angler catch and effort in recreational fisheries (e.g., MRFSS/MRIP), but potential biases exist. Malvestuto et al. (1978) provided an overview of creel surveys (specifically, roving creel surveys) and developed methods for obtaining catch-and-effort estimates from incomplete trips. However, biases in creel survey data still exist due to limited spatial coverage of surveys (NRC 2006) as well as heterogeneous probabilities of contacting various angler types. For example, Thomson (1991) discussed how the increased sampling of more avid anglers has the potential to bias total participation estimates and economic analyses. Some fisheries have large numbers of users who have private access to the resource, and interviewers have no way of intercepting them at a public access point (Ashford et al. 2010).

Angler logbooks, or diaries, are an alternate data source to traditional creel surveys and allow anglers to record their own fisheries data to later submit to managers or researchers. Though this format theoretically eliminates the public access bias, it can still suffer from other potential problems. Similar to intercept surveys, logbooks could have biases arising from an angler's experience (e.g., very avid or naïve) or his or her tendency to inflate the number and/or sizes of catches. Some new sources of biases can arise with this type of program, such as nonresponse bias, refusal, poor species identification, and inaccurate measurement. However, with proper support from an administrative body, angler diaries can provide valuable fisheries data at a much lower cost (Cooke et al. 2000).

Since 1979, NOAA has been employing an access-point intercept survey combined with a telephone survey to estimate catch and effort of marine recreational fisheries. Originally known as MRFSS, it began an effectively continuous revision process in 2006 following a critique by the NRC; now it is known as MRIP. The system uses telephone surveys of coastal residents for estimation of recreational fishing effort and a stratified, multistage cluster sample for the intercept surveys to estimate catch per unit effort (NRC 2006). Although the survey design is now believed to be largely unbiased, the fundamental challenges of sampling recreational anglers often results in high sampling variability, particularly at small spatial and temporal scales.

Recent attention has been given to developing methods of real-time data collection for fast, adaptive forms of fisheries management. This idea has become more palpable as smartphones and digital tablets have become more powerful and suitable for outdoor data collection (Gutowsky et al. 2013). Baker and Oeschger (2009) implemented a text message–based program to collect trip and catch information from for-hire captains. Stunz et al. (2014) had for-hire captains use an iPhone/iPad application (or app) called iSnapper in lieu of physical papers for their mandatory reporting of Red Snapper trips. In both studies, feedback was solicited from the users of the programs, and mainly positive reviews were received, even from those who were not initially familiar with text messaging or smartphone technology. One main advantage that electronic self-reporting apps have over traditional sampling programs, such as MRIP, is the ability to collect improved spatial data and comprehensive information on discarded fish. It is largely assumed that these programs will suffer the same biases as traditional angler diaries, but research is sorely needed to begin quantifying the extent of these issues.

One program initiated in 2012 is the Snook and Gamefish Foundation's iAngler app, instituted under its Angler Action Program family of apps. Through this app (available on all smartphones), users can submit information regarding a recreational fishing trip, such as time fished, mode of fishing, number of fish caught/released, length, weight, GPS location of fishing spots, and even a photograph of the fish. Because iAngler has not been critically assessed, its validity is in question. However, its discard information for Common Snook has already been included in state stock assessments (Muller and Taylor 2013), which means that a rigorous analysis is necessary to ensure that fisheries managers have a clearer understanding of the risks inherent in using such data. Given the existence of programs like these and the ever-increasing prevalence and capabilities of smartphones, electronic self-reporting fisheries data collection programs are expected to increase in popularity in the future.

There is a need to evaluate the validity of angler-reported catches from smartphone apps with respect to traditional creel survey data. In this study, we conducted a comparative study between the iAngler app and NOAA's MRIP survey, with a focus on its access-point intercept survey. The objective of this study was twofold: to (1) summarize the basic characteristics of the iAngler data set with respect to its extent of usage and participants and (2) compare iAngler and MRIP for spatial distribution of effort and mean catch per trip for commonly targeted sport fishes in Florida. By determining whether or not the data set provided by iAngler produces catch-and-effort values comparable to those of MRIP, we can suggest the appropriate contexts for using these self-reported data for future recreational fisheries management. This general methodology will also serve as a starting point for assessing the data quality of other opt-in, self-reporting fisheries sampling programs, which will likely become more prevalent in the future.

METHODS

MRIP

The MRIP data used in this study came from NOAA's online, publicly accessible database (st.nmfs.noaa.gov/recreational-fisheries/access-data/data-downloads/index), which contains the raw data collected in the access-point angler intercept surveys. The access-point intercept survey is hereafter referred to as the MRIP survey, because we did not include data from the MRIP telephone survey for our analysis.

We specifically worked with data in Florida from 2012 to 2013, the first two years of the iAngler app's operation, and, in some cases, worked with data by county. The species were chosen based on those that had sufficient data in iAngler (for comparisons), which included Common Snook, Spotted Seatrout *Cynoscion nebulosus*, and Red Drum. We then compared the data by mode (private boat and shore trips) and spatial designation (both statewide and smaller scale county clusters). The county clusters were chosen based on representation in the iAngler data set and included Atlantic (Brevard, Indian River, St. Lucie, Martin, Palm Beach, and Broward), Ft. Myers (Charlotte, Lee, Sarasota, and Collier), and Tampa (Hillsborough, Pinellas, and Manatee) counties.

For the purposes of counting trips, the number of trips was considered the number of ID codes that met the desired criteria. Thus, in using the term "effort," we do not refer to the actual fishing effort but the effort sampled by each respective program. Whenever catch is mentioned, this refers to the total catch of a given species—for the MRIP survey, the total catch value = $A1 + B1 + B2$, where $A1$ refers to harvested catch available for inspection, $B1$ refers to harvest unavailable for inspection (dead discards, already filleted, etc.), and $B2$ refers to live discards. In the MRIP survey, if a trip had no catch for a given species, the interviewer still noted the primary and secondary species targeted, if applicable. In this event, we considered only the primary species sought for calculating species-specific catch rates.

iAngler

All of the iAngler data were retrieved with the permission of the Snook and Gamefish Foundation. The iAngler data differs from those of MRIP in that users opt in and self-report all of the data through the app's interface. The app is open to the general public and, as of 2015, participation has been solicited via word of mouth, meaning that the sample population consists of an ambiguous or incomplete frame. The data collected are automatically stored in the Angler Action Program database, which includes other similar apps.

The number of trips in the iAngler database was considered as the number of unique trip IDs. Because iAngler only distinguishes between fish kept versus fish released, "catch" here implies total catch, which is represented by the sum of iAngler's quantity caught and quantity released.

The data used for comparisons consisted of MRIP surveys and iAngler submissions (self-reported fishing trips, saltwater only) for the entire state of Florida from 2012 to 2013. Comparisons were made between the number of reported trips by county and number of fish caught per trip. Because the MRIP and iAngler data were divided into catch, trip, and fish size, we used Microsoft Access to merge relevant trip and catch information pertaining to catch, location and duration of trips, and fish lengths.

General Data Comparison

We created distribution maps showing each county's percentage of total trips collected for Florida for both the iAngler and MRIP data sets and compared these relative proportions using a chi-square goodness-of-fit test. Because MRIP surveys are weighted according to expected fishing effort, the MRIP theoretically provides an unbiased spatial distribution of effort throughout the state. Thus, any differences in spatial fishing effort distribution between iAngler and MRIP are assumed to indicate a bias in spatial coverage of iAngler data.

We tabulated the total number of each data set's unique trip/intercept survey identifiers. In iAngler, there were separate entries not only for separate species in a given trip but also if the angler fished at different locations within that trip. For the purpose of determining the number of trips per county, we pooled the species and fishing spot identifiers and considered them one trip. We also extracted the number of iAngler users contributing to each county to calculate a mean submissions per user. In iAngler, a county that had a large number of reported trips would not be considered well represented if they all came from a small number of anglers.

Species-Specific Comparisons

The specific subsets for species, fishing mode, and spatial location were obtained by filtering according to state, county (when necessary), and then by species and fishing mode. All of the combinations of species (Common Snook, Spotted Seatrout, and Red Drum), mode (private boat and shore), and spatial designation (statewide, Atlantic cluster, Ft. Myers cluster, and Tampa cluster) were considered, for a total of 24 comparisons of mean catch/trip between iAngler and MRIP reported trips.

We created initial estimates of catch/trip for specific data subsets from iAngler and the MRIP survey by assuming that catch rate data followed a negative binomial distribution (i.e., high dispersion) and finding optimal mean and dispersion parameters for these distributions (e.g., Figure 1). We then randomly drew 10,000 pairs of catch/trip values from these iAngler and MRIP distributions and compared them. Each randomly drawn catch/trip value was generated by drawing mean and dispersion parameter values from their respective posterior distributions to account for uncertainty in the estimation of the mean and dispersion parameters (as opposed to drawing based on a maximum likelihood estimate alone). Posterior distributions were generated with a Metropolis-Hastings algorithm using the R package "MCMCpack," and posterior distributions were assumed to have converged when the Gelman-Rubin scale reduction factor for each parameter was less than 1.1 (Gelman et al. 1995). We present the 80% and 20% quantiles, as well as the median, for this resulting distribution. The 80% is included because in a likelihood ratio test framework, the 80% quantile would give an indication of the 95% confidence interval (Anderson 2007). Thus, if the 80% quantiles of a difference distribution included zero, the corresponding iAngler and MRIP catch/trip distributions were considered similar.

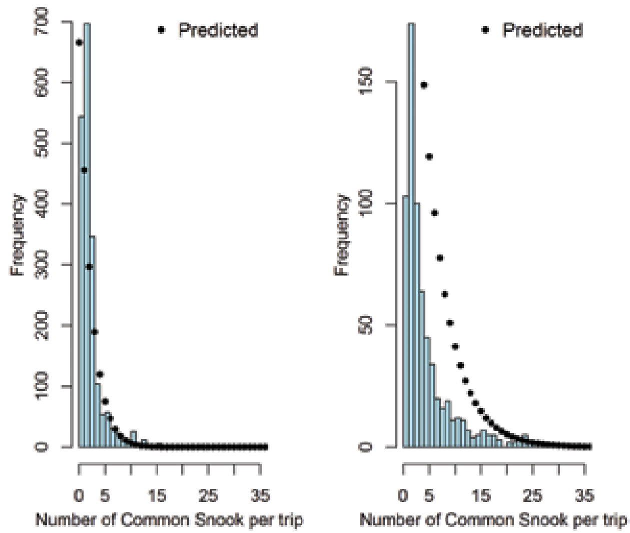

Figure 1. Sample plots showing the frequency distributions of number of Common Snook caught per trip in the private boat mode of (left) MRIP and (right) iAngler data sets in the Atlantic County cluster, 2012–2013. Black dots are the predicted values obtained from the fitted negative binomial distribution.

RESULTS

General Data Comparisons

One important feature of the iAngler data is that submissions are highly variable throughout Florida. From 2012 to 2013, the distribution of trips by county was significantly different from MRIP (χ^2 = 7,609, df = 34, P < 0.0001), which is likely a result of the high number of reported trips in the counties along the south-central Atlantic coast (Figure 2). The number of reported saltwater angling trips ranged from 0 (Clay, Jefferson, and Nassau counties) to 1,115 (Palm Beach), with a total of 3,572 trips (Table 1). For MRIP, the number of access-point interviews by county ranged from 40 (Walton County) to 7,686 (Pinellas County), with a mean of 1,837 and a median of 1,192 interviews. Of the counties that reported trips to iAngler, the mean number of trips was 90, and the median was 16. For those same counties, the number of different users of the app ranged from one (Baker, Dixie, Escambia, Flagler, Franklin, Putnam, St. Johns, Wakulla, and Walton counties) to 65 (Brevard), with a mean of 14 and a median of 6. The iAngler data set is characterized by high spatial variability, which could make it problematic if used for statewide-level assessment purposes.

Species-Specific Comparisons

The private boat mode is the most comprehensive mode in the iAngler data set. Median catch/trip values ranged from 0 to 2 fish for Common Snook, 2 to 4 for Spotted Seatrout, and 0 to 3 for Red Drum, with median catch rates being higher in MRIP for 11 of the 12 cases (Figure 3). There were enough trips (n >30) to make catch/trip comparisons for all of the species-mode combinations for all spatial designations (Figure 4). For the three species studied, all comparisons of catch/trip between iAngler and MRIP for the private boat mode resulted in similar distributions, suggesting similar catch rates (Figure 5). In all scenarios, the 20% quantiles lay to the right of zero, suggesting that the iAngler catch/trip values were overall larger across species and spatial designations than those of MRIP. Still, Common Snook in the Atlantic County cluster and Red Drum in the Ft. Myers and Tampa clusters were the only instances where the 20% quantile did not include zero, so there was ultimately a high degree of similarity between the two data

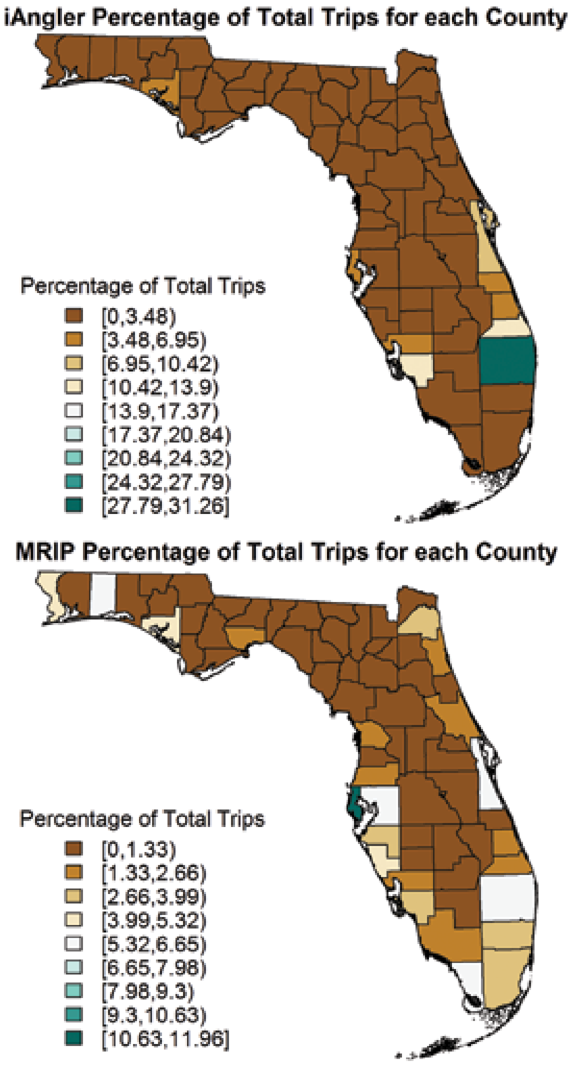

Figure 2. Maps comparing the distribution of trips by county between (top) iAngler and (bottom) MRIP.

sets' catch/trip estimates. This tendency toward zero for the 20% quantiles was seen even in some of the cases where the 80% quantiles were skewed farther to the right, which suggests that the central tendency of these difference distributions was near zero regardless of the degree of overdispersion seen in the catch/trip data. Overall, the iAngler data set provides catch/trip data similar to those of the MRIP survey for these three inshore species.

The shore mode was another commonly reported mode in the iAngler app's data set. Where data were sufficient, median catch rates ranged from 0 to 1 for Common Snook, 1 to 2 for Spotted Seatrout, and 0 to 1 for Red Drum, with median catch rates being higher for the MRIP data in four of the eight cases (Figure 6). Despite having some gaps in the data for both iAngler and the MRIP survey, the shore mode catch/trip values were similar when comparisons were possible. Comparisons were not possible for any of the species in the Tampa cluster or Spotted Seatrout in the Atlantic cluster, but sufficient data existed for the other spatial designations (Figure 7). For the rest of the scenarios, all comparisons suggest that the iAngler and MRIP catch/trip data are similar (Figure 8). In seven out of the eight comparisons, the difference in median catch/trip values

Table 1. Summary of the number (N) of saltwater angling trips per county and users reporting these trips. MRIP does not distinguish its reports by user, so there is no column for number of users or trips/user.

	iAngler				MRIP	
County	N trips	Proportion	N users	Trips/ user	N trips	Proportion
Bay	127	0.035	20	6.350	3,019	0.047
Brevard	316	0.088	65	4.862	3,926	0.061
Broward	31	0.009	17	1.824	1,725	0.027
Charlotte	170	0.047	16	10.625	1,077	0.017
Citrus	22	0.006	9	2.444	1,192	0.019
Clay	0	0.000	0	0.000	50	0.001
Collier	43	0.012	17	2.529	1,376	0.021
Dixie	27	0.008	1	27.000	285	0.004
Duval	11	0.003	8	1.375	2,265	0.035
Escambia	1	0.000	1	1.000	3,392	0.053
Flagler	2	0.001	1	2.000	371	0.006
Franklin	4	0.001	1	4.000	443	0.007
Gulf	20	0.006	6	3.333	414	0.006
Hernando	3	0.001	3	1.000	804	0.013
Hillsborough	99	0.028	31	3.194	3,679	0.057
Indian River	124	0.035	16	7.750	828	0.013
Lee	381	0.106	39	9.769	2,160	0.034
Levy	10	0.003	2	5.000	777	0.012
Manatee	29	0.008	10	2.900	2,555	0.040
Martin	398	0.111	52	7.654	1,475	0.023
Miami-Dade	21	0.006	14	1.500	2,213	0.034
Monroe	100	0.028	34	2.941	4,263	0.066
Nassau	0	0.000	0	0.000	471	0.007
Okaloosa	10	0.003	6	1.667	3,875	0.060
Palm Beach	1,115	0.311	50	22.300	3,896	0.061
Pasco	10	0.003	6	1.667	1,130	0.018
Pinellas	177	0.049	55	3.218	7,686	0.120
Santa Rosa	4	0.001	2	2.000	604	0.009
Sarasota	101	0.028	21	4.810	3,061	0.048
St. Johns	3	0.001	1	3.000	894	0.014
St. Lucie	125	0.035	33	3.788	1,169	0.018
Taylor	6	0.002	3	2.000	674	0.010
Volusia	73	0.020	24	3.042	1,548	0.024
Wakulla	1	0.000	1	1.000	952	0.015
Walton	1	0.000	1	1.000	40	0.001

was zero. In addition, when compared to the private boat mode, the 80% quantiles for the shore mode comparisons are tighter. Taken together, these two points indicate that the iAngler and MRIP data have not only similar central tendencies but similar dispersions as well. The shore mode of iAngler has considerably fewer trips in the Tampa cluster but actually exceeds the total number of MRIP trips for nearly all cases in the other two clusters (especially Common

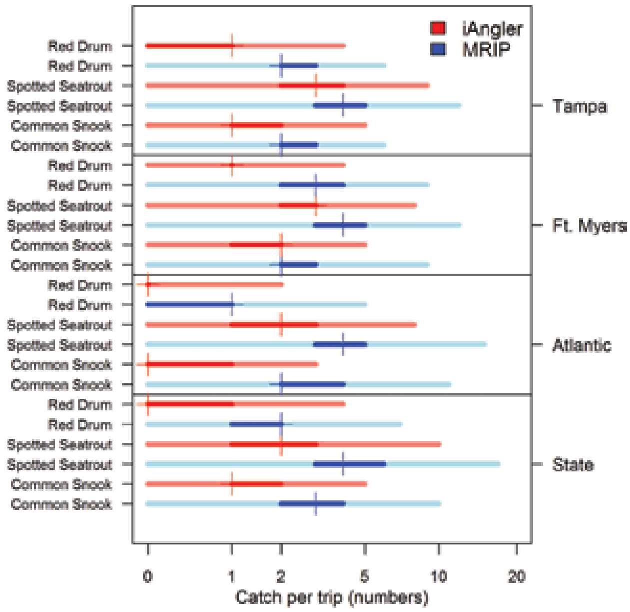

Figure 3. Simulated catch rate distributions for iAngler and MRIP reported trips in the private boat mode. Crosses represent the median, dark bars represent the 20% quantiles, and light bars represent the 80% quantiles.

Snook). In these events, the mean catch rate data for iAngler are very similar to those of the MRIP survey.

DISCUSSION

The high degree of similarity between catch rate data from the iAngler smartphone app and the MRIP survey suggests that an electronic self-reporting framework can provide information that is usable for the assessment of recreational fisheries. For fish species where iAngler has adequate sample size (e.g., Common Snook, Spotted Seatrout, Red Drum), the data could be useful for fishery-dependent uses in stock assessment. Although the spatial bias of iAngler makes it inappropriate for usage at a statewide level, this study used only the first 2 years of the app, when knowledge of the app was spread exclusively by word of mouth (Brett Fitzgerald, Snook and Gamefish Foundation, personal communication). The fact that the iAngler and MRIP catch/trip values were similar when compared at an appropriate spatial resolution (i.e., the county clusters) shows the ability of an electronic self-reporting program to provide representative catch rate data. Such a program cannot realistically replace existing survey methods but may have the potential to fill data gaps, especially with regard to discarded fish and small, spatially diffuse fisheries. Additionally, the coverage is limited by the fact that not all anglers own a smartphone. Though many of the concerns over self-reported fisheries data were left unaddressed by this analysis, we believe this to be a crucial first step in analyzing app-based programs.

The iAngler smartphone app is analogous to paper-based angler diaries, which have been useful in recreational fisheries. Long-term angler diary programs have provided valuable information for monitoring stock status over time (Sztramko et al. 1991; Kerr 1996). In some cases, when the program runs long enough, it can be used to assess the fishery before and after a major management action such as a change in minimum length limit (MacLennan 1996). In such cases, an angler diary presents an opportunity for a natural experiment, where managers can assess the effect regulations have on fishing behavior and stock

State	666/ 1930	633/ 9846	546/ 7093
Atlantic	434/ 409	321/ 1143	259/ 883
Ft. Myers	91/ 684	115/ 1356	122/ 1244
Tampa	107/ 703	113/ 3082	105/ 1953
	Common Snook	Spotted Seatrout	Red Drum

iAngler poor
MRIP poor
Both poor
Both sufficient

Figure 4. Summary of data quality in relation to comparing the catch/trip distributions for all private boat mode trips. Each cell contains the number of trips for (top) iAngler and (bottom) MRIP, where n = 30 is the minimum number of samples required to fit to a negative binomial distribution. Each color indicates which, if either, data set had enough records.

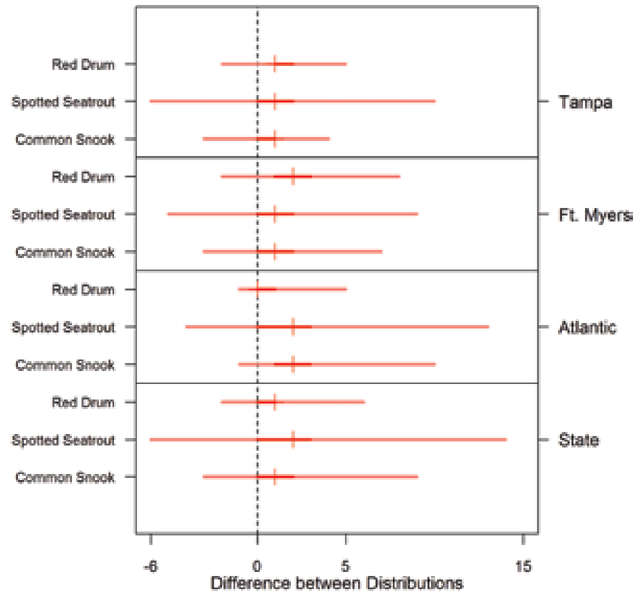

Figure 5. Difference between iAngler and MRIP simulated catch/trip distributions for the private boat mode. Crosses represent the median, dark red bars represent the 20% quantiles, and light red bars represent the 80% quantiles.

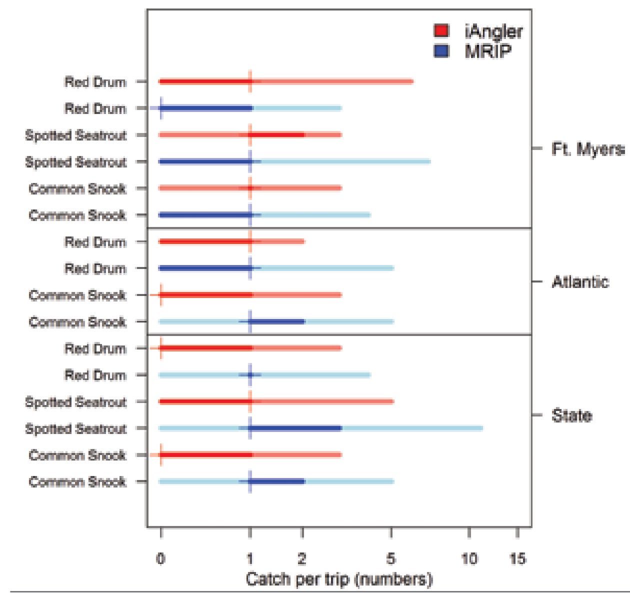

Figure 6. Simulated catch rate distributions for iAngler and MRIP reported trips in the shore mode. Crosses represent the median, dark bars represent the 20% quantiles, and light bars represent the 80% quantiles.

State	921/ 361	362/ 559	246/ 558
Atlantic	573/ 22	123/ 29	59/ 112
Ft. Myers	326/ 81	217/ 58	105/ 69
Tampa	14/ 48	13/ 243	10/ 88
	Common Snook	Spotted Seatrout	Red Drum

iAngler poor
MRIP poor
Both poor
Both sufficient

Figure 7. Summary of data quality in relation to comparing the catch/trip distributions for shore mode trips. Each cell contains the sample size for (top) iAngler and (bottom) MRIP, where n = 30 is the minimum number of samples required to fit to a negative binomial distribution. Each color indicates which, if either, data set had enough records.

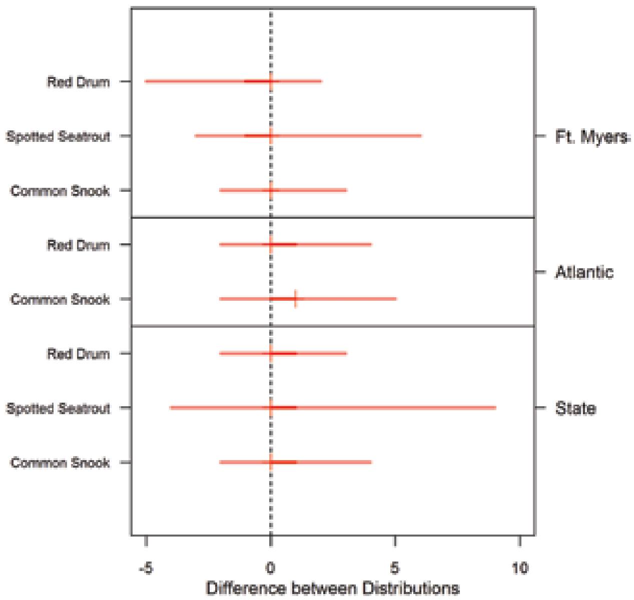

Figure 8. Difference between iAngler and MRIP simulated catch/trip distributions for the shore mode. Crosses represent the median, dark red bars represent the 20% quantiles, and light red bars represent the 80% quantiles.

status. Ebbers (1987) showed that angler-supplied information regarding length-frequency distributions, mortality rates, and population estimates was similar to the equivalent data obtained by fishery-independent surveys. In addition, because diaries allow anglers to report data right after a trip is taken, they are not as vulnerable to a recall bias as traditional mail surveys. In fact, diaries were used to reduce the recall bias on the mail-based Illinois Sport Fishing Survey (Tarrant et al. 1993). The simple nature of a smartphone-based angler diary app could conceivably replace mail surveys and paper-based diaries if administered and monitored by a state fisheries agency. Diaries also have the advantage of addressing the public access bias, which occurs when a large number of trips in a fishery are taken from private access points (Ashford et al. 2010). However, an electronic smartphone-based reporting system would represent a simpler and cheaper method to correct this problem. Further, studies that have implemented the use of smartphone- and digital tablet–based reporting programs have noted that most participants prefer them to paper-based logbooks (Baker and Oeschger 2009; Stunz et al. 2014). Thus, if such electronic self-reporting angler diaries were to be employed and controlled in the same way as traditional diaries, they could prove to be an even better method for collecting information from recreational anglers. Unfortunately, the success of these programs depends on recreational anglers of all typologies having a smartphone, which is not yet the case. A potential solution would be to allow anglers to choose a paper-based diary whose information can be later uploaded onto the online database, which is how the Snook and Gamefish Foundation's Angler Action Program began (Brett Fitzgerald, Snook and Gamefish Foundation, personal communication).

Our study was the first to rigorously analyze opt-in, self-reported recreational fisheries data from electronic data collection (e.g., a smartphone app) with a focus on the private angling modes. Stunz et al. (2014) used a smartphone/tablet app called iSnapper to record data from headboat and private charter boat (collectively, the for-hire sector) trips with a focus on the Red Snapper fishery. However, their study involved choosing 16 captains to become involved with the program and was relatively controlled, whereas our work with iAngler has been on a data set consisting of true opt-in participants. Though their study had the added benefit of a pre- and postuse survey to gauge captains' interest in the app, it did not include a rigorous comparison to other data collection programs. Stunz et al. (2014) highlighted the difference between for-hire vessel captains and the private recreational angling population, calling for a study on that specific mode, and our analysis has begun filling that gap. This study has shown that when a proper sample size of trips exists, an electronic self-reporting platform like the iAngler app could provide a valid measure of catch per unit effort. For example, as the program runs for more years, these catch rate data could be used as a time series to assess relative abundance. However, the adequate representation of the entire angling population is also an important factor in properly sampling recreational fisheries, but this was not possible to assess with our analysis.

Self-reporting fisheries data apps possess some advantages that would allow them to supplement current data collection methods. An app like iAngler allows for more comprehensive information on discarded fish (length, weight, hooking location, higher spatial resolution), which could theoretically augment stock assessments in a way that the MRIP survey is not capable of doing. In addition, electronic self-reporting apps can provide supplementary data for spatially diffuse, low-effort fisheries, where a small number of MRIP estimates leads to volatile estimates. For example, in Virginia's Blueline Tilefish *Caulolatilus microps* fishery, the MRIP survey estimated zero catches for 5 of the 6 years from 2009 to 2014, whereas mandatory recreational reporting records for the state indicated over 1,000 fish caught per year (Joe Cimino, Virginia Marine Resources Commission, personal communication). Further, in a mandatory reporting framework, many of the biases concerning selection of participants and drop-off become irrelevant, because all of the trips taken by anglers are then assumed to be sampled. The only necessary step would be to provide a paper logbook option for anglers without a smartphone or tablet. Overall, we found that the iAngler smartphone app can provide valuable recreational fisheries data for certain species, especially popular inshore species in urbanized regions of Florida.

There were similarities in the catch/trip data for the three inshore species studied (Common Snook, Spotted Seatrout, and Red Drum). Previous investigations have suggested a bias in self-reported data for measures such as catch rates (Didden 2012), but in this case the catch/trip data were very similar between collection methods. The most consistently similar distributions of catch/trip between iAngler and MRIP were for the shore mode. Though the comparisons for the private boat mode were skewed to the right, they still suggested that the iAngler data were similar to the catch/trip values provided by the MRIP survey. The fact that the median values were generally higher in the MRIP's data suggests that the majority of trips reported to the iAngler app actually had lower catch rates. However, the overall skew, when looking at the differences in catch rate distributions (with iAngler's rates higher overall), could mean that there are a few iAngler users who have extremely high catch rates relative to the majority of the angling population. A way to address this would be a correction factor effectively downweighting these potentially avid, skilled anglers who might be biasing the overall catch rates. In general, these results are promising, especially for Common Snook, because the results of its 2013 stock assessment update called for supplementing data from the private boat and shore modes (Muller and Taylor 2013). Unfortunately, these results are for the three most popularly reported species, so even assuming that these data are reliable, the iAngler app would still be extremely limited in its scope. In the future, electronic apps like this may be best utilized by actively soliciting data for fisheries that are undersampled by MRIP.

One possible point of contention we address here is the issue of weighting the catch values for the catch/trip comparisons. The MRIP data include sampling weights for each recorded interview, but they were not included in our analysis mainly because only relative values were of interest for the comparisons themselves. Weighting would not add to the utility of the results, because they would be applied equally to both MRIP and iAngler, depending on the time and location of the fishing trip. Additionally, because total catch and total effort are not considered, the use of weights to expand estimates does not apply. Thus, the comparisons were made with raw data from both data sets, under the assumption that the weighting would not change the results of our fitting and simulation process.

Despite the potential advantages of using electronic self-reporting apps to measure catch rates, many biases that plague most angler survey methods still likely exist. For example, in an angler diary study in Texas, Prentice et al. (1993) found that participation dropped off considerably from the first to the second year, when active recruitment ceased. Within the iAngler framework, it would be difficult to tell whether a drop in reported trips was from nonuse of the app or less fishing by the angler. Within that same study, Largemouth Bass *Micropterus salmoides* diary catch rates were significantly related to creel survey catch rates, but the relationship was still variable. Bray and Schramm (2001) also failed to find a strong relationship between diary catch rates and creel survey catch rates for black bass and crappie fisheries. They also found that those using the diary were more avid, affluent, and invested in fisheries management (e.g., attending public hearings). Both studies caution against angler diaries replacing traditional survey methods but suggest alternative usages. For example, Prentice et al. (1993) mentioned using these programs as warnings, so that drastic changes in logbook data could prioritize more rigorous sampling by researchers to investigate potential problems in a fishery. Bray and Schramm (2001) emphasized the difficulty of creel surveys gathering comprehensive data on discards and for spatially diffuse fisheries. Though smartphone-based apps cannot exist as the sole source of data, they could conceivably fill both of these roles. Further, they could perhaps serve as a default collection method for fisheries that mandate data reporting, where problems of nonresponse, drop-off, and representativeness would not be different than those of any other method.

Angler avidity is an issue deserving of attention because it affects not only volunteer programs but also those such as creel surveys. For example, though a properly stratified survey (e.g., MRFSS/MRIP) should not suffer from an avidity bias when calculating catch rates, the increased sampling of high-frequency users can affect economic analyses and estimates of total participation (Thomson 1991). The effects in such programs should be minimal compared to a volunteer, self-reporting program like iAngler mainly because of the app's small sample size and potentially biased pool of users. However, if the magnitude of the avidity remains constant, it is not an issue if catch rates are used as a relative index of abundance; such data simply could not be used for population-level, absolute catch rate estimates. Jiorle et al. (2015) used a simulation-evaluation framework to develop and test a weighting factor that explicitly accounted for both zero-catch trips and the disproportionately high frequency of large catch/trip values from avid anglers. The weighting factor used was based on a geometric mean developed by Habib (2012), which incorporated zero values. When this weighting factor was applied to catch rates of Common Snook, Spotted Seatrout, and Red Drum from the iAngler app, the values decreased for four, five, and four combinations of year and spatial area, respectively (out of six scenarios for each). This suggested that the avidity bias exists in the iAngler data but that it can be corrected for. A shortcoming of this analysis was that it assumed that an angler reported 100% of trips taken. However, if each angler's reporting rate to the app is known—something possible within the framework of such apps—avidity could be accurately addressed. Certain other developments would be necessary to instill more confidence in the use of app-based data collection programs. First, ideally, all recreational anglers would have access to a smartphone or digital tablet. A way to estimate the percentage of those who do would be a survey contacting anglers who have signed up in NOAA's National Saltwater Angler Registry. Second, many studies emphasize the impact that variable reporting rates can have on conclusions about effort/participation drawn from angler diary programs (Tarrant et al. 1993; Connelly and Brown 1995; Connelly et al. 2000). One app feature that might allow the determination of a crude individual-angler reporting rate for iAngler app users would be an "I fished" button. This would be an easy, one-click measure that an angler might be more consistent about using than remembering and/or having the time to fill out the information from an entire fishing trip. That way, the number of fully submitted trips could be combined with the "I fished" button to obtain a rough reporting rate for each angler. This would help to explicitly address biases resulting from overrepresentation of avid anglers. Finally, if demographic information were required—or at least solicited on a volunteer basis—much more could be learned about iAngler users.

There are many additional avenues for future research on this subject, especially if the iAngler app is further revised to collect other important fisheries data. First, we recommend a continuation of our analysis, because two years is not long enough to capture long-term trends in fisheries. An avenue that could be explored in the future is a comparison of individual fish lengths between iAngler and the MRIP survey. Because of the short time period used (2012–2013) and the fact that anglers are not required to report lengths of fish into the app, there were not enough length records to perform a reliable comparison. However, providing size structure information for stock assessments would be useful, especially for developing an ecosystem-based approach to fisheries management (Shin et al. 2005). Outside the scope of our study was a more in-depth look at the validity of iAngler's data on discarded fish. Unlike the MRIP survey, iAngler contains the lengths and weights of some of the discarded fish. A study that validates the accuracy of this discard information is of the highest priority, because the lengths of discarded Common Snook have already been incorporated into its most recent stock assessment (Muller and Taylor 2013). The importance of understanding discards cannot be emphasized enough, because the success of the commonly applied minimum size limit regulation is hinged upon the fate of undersized discards (Coggins et al. 2007).

In conclusion, we have developed a method for analyzing electronic self-reporting apps used in recreational fisheries and shown the potential utility for the iAngler app to provide catch rates similar to those of the MRIP survey. Still, studies on the demographics of the users and their individual trip reporting rates are sorely needed. Because the app is also equipped to submit other metrics such as lengths and weights of released fish, GPS coordinates of catch, and condition of released fish, it has the potential to provide novel information that the MRIP is not designed to collect—even if such data are not currently robust enough for analysis. Gutowsky et al. (2013) summarized the current uses of smartphone and digital tablets for fisheries science, suggesting that growing technology and usage of smartphones will make such programs more attractive and useful in the future. Thus, with consistent backing and revision, the utility of electronic self-reporting programs for recreational fisheries management has the potential to grow, making them a valuable tool for managers and users.

REFERENCES

Anderson, D. R. 2007. Model based inference in the life sciences: a primer on evidence. Springer Science and Business Media, New York.

Ashford, J., C. Jones, L. Fegley, and R. O'Reilly. 2010. Catch data reported by telephone avoid public access bias in a marine recreational survey. Transactions of the American Fisheries Society 139:1751–1757.

Baker, M. S., and I. Oeschger. 2009. Description and initial evaluation of a text message based reporting method for marine recreational anglers. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1:143–154.

Bray, G. S., and H. L. Schramm, Jr. 2001. Evaluation of a statewide volunteer angler diary program for use as a fishery assessment tool. North American Journal of Fisheries Management 21(3):606–615.

Coggins, L. G., M. J. Catalano, M. S. Allen, W. E. Pine, and C. J. Walters. 2007. Effects of cryptic mortality and the hidden costs of using length limits in fishery management. Fish and Fisheries 8:196–210.

Coleman, F. C., W. F. Figueira, J. S. Ueland, and L. B. Crowder. 2004. The impact of United States recreational fisheries on marine fish populations. Science 305:1958–1960.

Connelly, N. A., and T. L. Brown. 1995. Use of angler diaries to examine biases associated with 12-month recall on mail questionnaires. Transactions of the American Fisheries Society 124:413–422.

Connelly, N. A., T. L. Brown, and B. A. Knuth. 2000. Assessing the relative importance of recall bias and nonresponse bias and adjusting for those biases in statewide angler surveys. Human Dimensions of Wildlife 5(4):19–29.

Cooke, S., W. Dunlop, D. Macclennan, and G. Power. 2000. Applications and characteristics of angler diary programs in Ontario, Canada. Fisheries Management and Ecology 7:473–487.

Didden, J. 2012. Summary of Feb 2, 2012 workshop on opt-in angler panels. Mid-Atlantic Fishery Management Council, Baltimore, Maryland

Ebbers, M. A. 1987. Vital statistics of a Largemouth Bass population in Minnesota from electrofishing and angler-supplied data. North American Journal of Fisheries Management 7(2):252–259.

Gelman, A., J. B. Carlin, H. S. Stern, and D. Rubin. 1995. Bayesian data analysis, 2nd edition. Chapman and Hall, London.

Gutowsky, L. F. G., J. Gobin, N. J. Burnett, J. M. Chapman, L. J. Stoot, and S. Bliss. 2013. Smartphones and digital tablets: emerging tools for fisheries professionals. Fisheries 38:455–461.

Habib, E. A. 2012. Geometric mean for negative and zero values. International Journal of Research and Reviews in Applied Sciences 11:419–432.

Jiorle, R. P., R. Ahrens, and M. S. Allen. 2015. Determining the utility of electronic, self-reported recreational data for fisheries stock assessment. Master's thesis. University of Florida, Gainesville, Florida.

Kerr, S. J. 1996. A summary of Muskies Canada Inc. angler log information, 1979–1994. Ontario Ministry of Natural Resources, Science and Technology Transfer Unit, Kemptville, Ontario.

MacLennan, D. 1996. Changes in the Muskellunge fishery and population of Lake St. Clair after an increase in the minimum size limit. Ontario Ministry of Natural Resources, Southern Region, Science and Technology Transfer Unit Workshop Proceedings WP-007, Kemptville, Ontario, Canada.

Malvestuto, S. P., W. D. Davies, and W. L. Shelton. 1978. An evaluation of the roving creel survey with nonuniform probability sampling. Transactions of the American Fisheries Society 107(2):255–262.

Muller, R. G., and R. G. Taylor. 2013. The 2013 stock assessment update of Common Snook, *Centropomus undecimalis*. Florid Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, St. Petersburg, Florida.

NRC (National Research Council). 2006. Review of recreational fisheries survey methods. National Academy of Sciences, Washington, D.C.

NOAA (National Oceanic and Atmospheric Administration). 2012. Final Reef Fish Framework Action to the Fishery Management Plan for the Reef Fish Resources of the Gulf of Mexico. Gulf of Mexico Fishery Management Council, National Marine Fisheries Service, St. Petersburg, Florida.

———. 2016. Marine Recreational Information Program. Available: st.nmfs.noaa.gov/.

Pereira, D. L., and M. J. Hansen. 2003. A perspective on challenges to recreational fisheries management: summary of the symposium on active management of recreational fisheries. North American Journal of Fisheries Management 23(4):1276–1282.

Post, J. R., M. Sullivan , S. Cox, N. P. Lester, C. J. Walters, E. A. Parkinson, A. J. Paul, L. Jackson, and B. J. Shuter. 2002. Canada's recreational fisheries: the invisible collapse? Fisheries 27(1):6–17.

Prentice, J. A., B. W. Farquhar, and W. E. Whitworth. 1993. Comparison of volunteer angler-supplied fisheries catch and population structure data with traditional data. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 47(1993):666–678.

Shin, Y.-J., M.-J. Rochet, S. Jennings, J. G. Field, and H. Gislason. 2005. Using size-based indicators to evaluate the ecosystem effects of fishing. ICES Journal of Marine Science: Journal du Conseil 62:384–396.

Stunz, G. W., M. Johnson, D. Yoskowitz, M. Robillard, and J. Wetz. 2014. iSnapper: design, testing, and analysis of an iPhone-based application as an electronic logbook in the for-hire Gulf of Mexico Red Snapper fishery. Harte Research Institute for Gulf of Mexico Studies, Texas A&M University–Corpus Christi, Final Report to National Marine Fisheries Service, Grant NA10NMF4540111, Corpus Christi, Texas.

Sztramko, L., W. Dunlop, S. Powell, R. Sutherland, and D. Guthrie. 1991. Applications and benefits of an angler diary program on Lake Erie. Pages 520–528 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollock, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society Symposium 12, Bethesda, Maryland.

Tarrant, M. A., M. J. Manfredo, P. B. Bayley, and R. Hess. 1993. Effects of recall bias and nonresponse bias on self-report estimates of angling participation. North American Journal of Fisheries Management 13(2):217–222.

Thomson, C. J. 1991. Effects of the avidity bias on survey estimates of fishing effort and economic value. Pages 356–366 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollock, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society Symposium 12, Bethesda, Maryland. AFS