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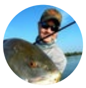

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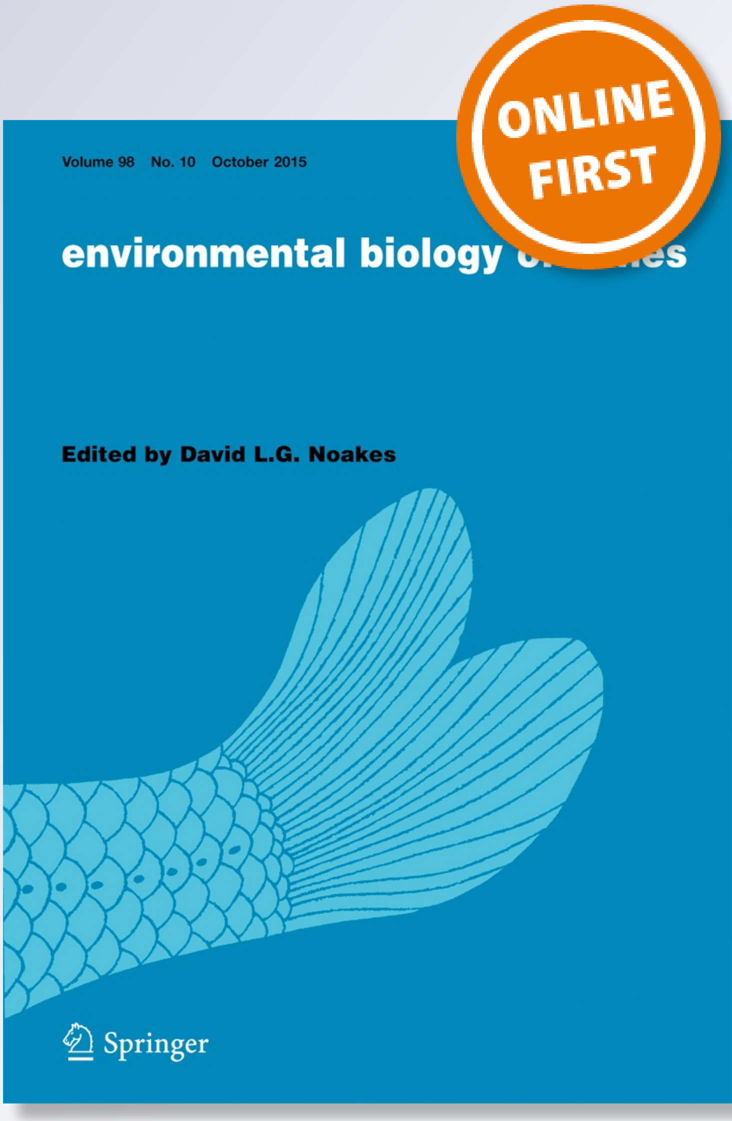

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An overview of the tarpon genetic recapture study in Florida – a citizen science success story

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Abstract The tarpon Genetic Recapture Study started in an effort to determine how often a tarpon is caught and released in Florida's growing and lucrative fishery by using DNA fingerprinting techniques as a tool to identify and track individual tarpon. Previous research on central and southwest Gulf of Mexico fisheries showed that most tarpon can survive short-term catch-and-release fishing practices. However, fishing pressure is intense during peak season, and tarpon fishing varies in time and space throughout the state. In this study, a novel method of obtaining fish tissue replaced traditional fin clipping, and citizen-scientists were utilized to collect DNA samples and record capture information from tarpon they caught. Benefits of using citizen scientists included being able to sample fish statewide and collect data on a species that is difficult to catch in great number. From the pilot study in 2005 through the study's end in 2014, 24,572 samples were received from volunteer anglers throughout the coastal southeastern United States, and of those, 22,992 were collected from tarpon caught in Florida waters. tarpon samples were returned from fish caught along the Gulf and Atlantic Coasts and Florida Keys, but regionally the database was depauperate in samples from north Florida. Public outreach was a critical and integral component of study promotion and angler involvement. Future work based on recapture data will provide information needed to estimate recapture rates, evaluate seasonal and regional movement patterns, determine site fidelity, establish connectivity of tarpon in Florida waters and over the long-term could determine if juvenile tarpon sampled within Florida nursery habitats supply the adult fishery.

Keywords Tarpon · Genetics · Mark-recapture · Citizen science · *Megalops atlanticus*

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Introduction

Since recorded history there has been fishing pressure on Atlantic tarpon (*Megalops atlanticus*, Valenciennes, 1847). There are written accounts of Native Americans fishing for tarpon, smoking tarpon jerky and hanging fish for bragging rights in the late 1800s (Mygatt 1890; Oppel and Meisel 1987). Today, tarpon support a large, lucrative and growing sport fishery in Florida (Barbieri et al. 2008). tarpon fishing generates millions of dollars for the state's economy (Fedler 2011) and is part of the greater billion dollar saltwater recreational fishing industry (2006 US Fish and Wildlife Service Report). Fedler's (2011) survey of resident saltwater fishing license holders in three areas of Florida revealed that direct expenditures for tarpon fishing were $102 million, $64 million and $11 million dollars in the

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Everglades, Charlotte Harbor and St. Lucie River, respectively. The total economic impact of the fishery in those areas was $302 million dollars, and the fishery is ubiquitous to Florida (Fig. 1).

In Florida, direct harvest of tarpon is rare. There is no commercial tarpon fishery and what was already a recreational fishery with less than a 1 % harvest (Adams et al. 2013) became a mandatory catch-and-release sport fishery in September 2013. Recreational fishing pressure remains intense when tarpon are present in local waters, particularly during the April through July spawning season (Crabtree et al. 1997). As a result of increased fishing pressure and catch-and-release practices, most state-funded tarpon research programs during the last decade focused on questions surrounding the effects of catch-and-release angling on tarpon stress and survival (Guindon 2011). From the literature we also know that fishing pressure and catch-and-release practices have the potential for indirect impacts on fish populations (Lewin et al. 2006). Understanding these effects is particularly important, especially since the 2011 International Union for the Conservation of Nature (IUCN) Red List Assessment Workshop International Union for the Conservation of Nature assigned the species a vulnerable conservation status (Adams et al. 2013). An acoustic telemetry study to estimate short-term, post-release survival rates of tarpon in Boca Grande Pass and Tampa Bay, Florida fisheries found that approximately 87 % of the tracked fish survived (Guindon 2011). There was a 95 % post-release survival rate when data associated with mortalities from potential shark attacks were removed from the analyses (Guindon 2011). Most tarpon survived over the short term if handled with care prior to release, but it was undetermined how often anglers fishing in concentrated fishing grounds catch and release the same tarpon.

Tagging and marking individual fish is a common tool in fishery science that has provided much information about fish species and their movements, migrations, site fidelity, spawning habitat, reproductive biology, survival rates, growth rates, catch rates, stock identification, and abundance (Parker 1990; Pine et al. 2003). Originally we planned to implement an angler-based dart-tagging program to evaluate recapture rates within Florida's recreational tarpon fishery such as that led by The National Oceanic and Atmospheric Administration (NOAA) Fisheries Service from 1960 to 1999. Science and technology advanced so quickly that the Florida Fish and Wildlife Conservation Commission's (FWC) Fish and Wildlife Research Institute (FWRI) commenced a pilot study in 2005 to test the veracity of using a tarpon's DNA as a permanent biological "marker" to identify and track individual fish. Establishing the suitability of using DNA fingerprinting applications for a tarpon mark-recapture study (Seyoum et al. 2007) eliminated the plan for dart tags. Using DNA as a marker precludes other issues often associated with conventional tagging programs, such as the assumption of no tag loss (Pine et al. 2003) or relying on the use of batteries or satellites to function. The goals of this study were to describe a novel noninvasive method to obtain tissue samples from fish for DNA analysis without fin clipping, and to engage volunteer anglers as citizen scientists in the participation of a mark-recapture study on tarpon in an effort to expand the breadth of knowledge on the stock and its spatially complex fishery.

Materials and methods

Sample collection

Anglers acting as citizen-scientists collected DNA from tarpon throughout Florida and other states (Fig. 1) using a sampling kit provided by FWRI and partners Mote Marine Laboratory (MML). The sampling kits included enough supplies to take noninvasive DNA samples and record the corresponding capture information from three individual fish. This consisted of: three data slips printed on waterproof paper to record fish capture date, time, county, location, approximate total length, time it took to catch the fish, and angler contact information; one number 2 golf pencil; three, 20 mL plastic vials labeled with a unique sample number containing 20 % EtOH storage solution; three rectangular pieces of 3 M© abrasive scrub pads; and a folded instruction sheet describing the study background, objectives, and methods for taking a DNA sample. The kits were assembled by MML volunteers, and were provided at no cost to anglers, to participating shops that assisted with kit distribution, and to coordinators of angling events targeting tarpon (tournaments).

Sampling kits were obtained on request by emailing, calling a toll free number, or by visiting a participating bait and tackle shop. The shops' involvement as statewide participants was critical for promoting the study, distributing the sampling kits, and encouraging local

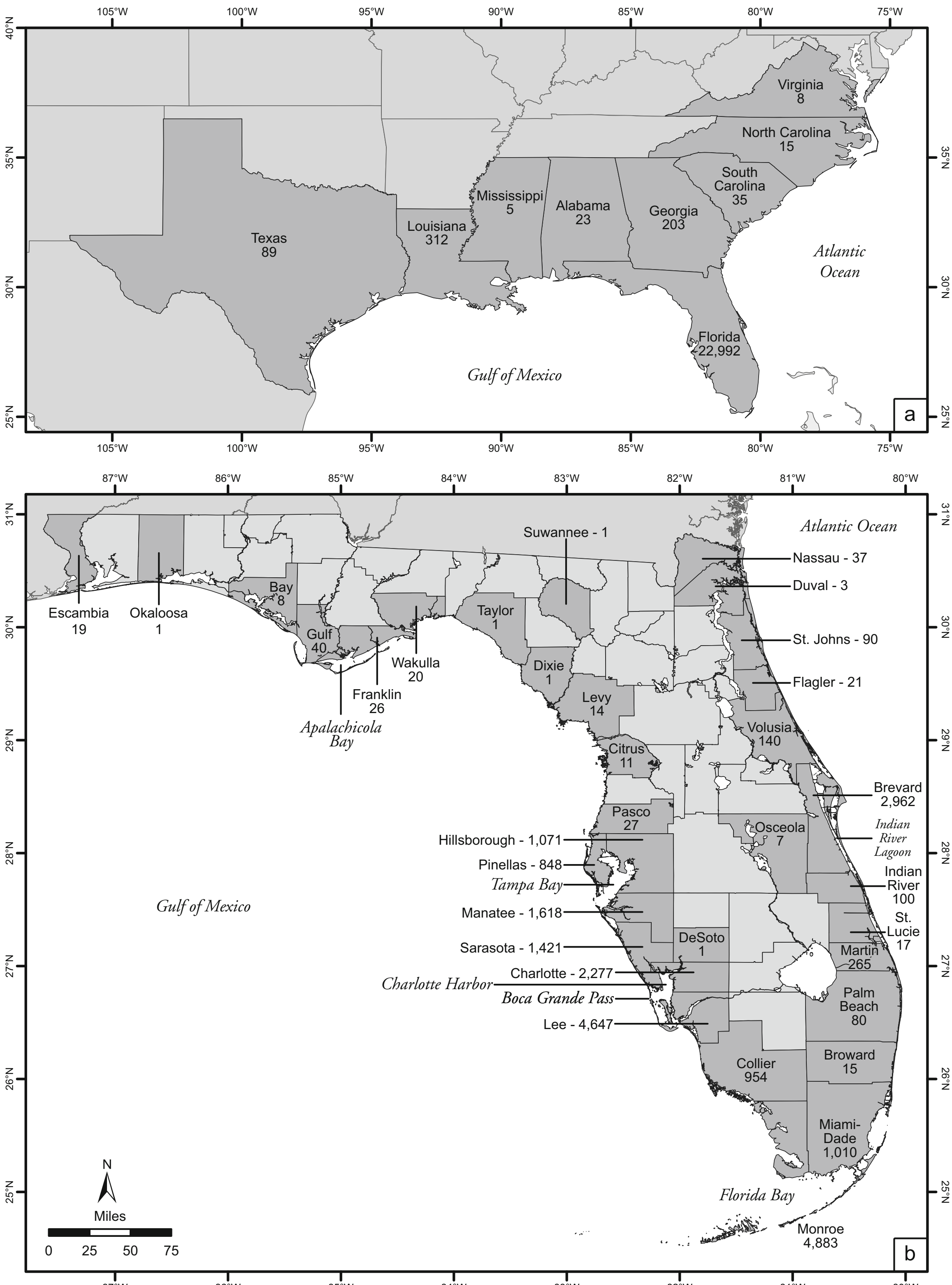

Fig. 1 Tarpon DNA samples returned from 2005 to 2014 by anglers in the southeast United States (**a**) and in Florida, sample distribution is further broken down by county (**b**). Water bodies were italicized. A total of 355 Florida samples were returned with no county or location information

angler participation. They were provided with DNA sampling kits, a plastic box for kit storage (if requested), poster for display, promotional brochures and tarpon fact sheets for distribution to the public, and FWRI and MML contact information. The shops also served as sample drop off locations for return to FWRI at no cost to the angler. The number of shops fluctuated as ownership changed, shops moved or closed, and new ones opened; at the end of the study there were 221 participating shops located in the following regions of Florida: Northwest (46), West Central (48), Southwest (31), Everglades (3), Florida Keys (38), Southeast (31), East Central (17), and Northeast (7). There were also three out-of-state shops located in Fairhope, Alabama, Atlanta, Georgia, and Pawley Island, South Carolina. In addition to the shops that served as kit distribution centers, 191 other locations such as public and private marinas, coastal boat ramps, and angler businesses around the state displayed a TGRS poster promoting project awareness. Scientific staff contacted the shops monthly to retrieve DNA samples and to resupply DNA sampling kits. Alternatively, anglers had the option of returning their samples directly to FWRI or MML by mail or personal delivery.

All tarpon in this study were caught, handled and released in the wild according to routine recreational fishing practices and ethics of individual anglers and state fishing regulations outlined by FWC management staff. Scientific staff did not perform any experimental studies with fish maintained in captivity for the purposes of this study. In 2005 and 2006, fin clipping was the method used to obtain tissue samples for DNA analysis. Wydoski and Emery (1983) showed that partial clips of dorsal fins could be used as short-term marks without adverse effects on survival or metabolism. While fin clipping is a common, relatively harmless method of obtaining DNA samples from fish, a series of trials during the 2006 tarpon season revealed a simpler method (Fig. 2). The jaw scrape technique helped to overcome sampling challenges created by the size, demeanor, and strength of some tarpon, such as trying to control a large tarpon with one hand while trying to use a pair of scissors to take a dorsal fin clip with the other hand. Fin clipping adult tarpon was nearly impossible without a minimum of two people. The new technique, implemented in 2007, required less fish handling and in most cases could be performed by one person while the tarpon was still in the water at the side of the boat. One hand controlled the fish by holding the leader or lower jaw, and the free hand could scrape the outer jaw of the tarpon with the abrasive pad to gather a small sample of skin cells (Fig. 2). Keeping large tarpon in the water at the side of a boat during angling events was always encouraged by staff for the safety of the fish and angler, and became mandatory for all tarpon over 40 in. (101.6 cm) according to state regulatory changes in September 2013. For tarpon less than 20 cm FL, anglers were asked to remove a scale for DNA and not to scrape the jaw. Training tools provided to anglers for taking a DNA sample included written instructions within each kit, an educational online video produced by Florida Sea Grant and the University of Florida Institute of Food and Agricultural Sciences Communications, and personal instruction when scientific staff attended public outreach events. Because of Florida's geographic scale and its spatially complex fishery impossible to cover with staff, various website articles were written to address common inquiries and an email account was established to give the public direct access to scientific staff.

Sample processing and analysis

All DNA samples and associated catch information recorded on data slips were ultimately returned to FWRI. Data slips were checked for accuracy and if needed angler inquiries were made by staff to verify questionable or incomplete information. An estimate of life history stage (mature adult or immature juvenile/subadult) was assigned based on the length estimates provided by the anglers. The average size of sexual maturity for female tarpon in Florida is 1,285 mm (51.4 in.) and 1,175 mm (47 in.) for males (Crabtree et al. 1997); therefore, tarpon 1,219 mm (48 in.) and larger were considered adults for the purposes of this study. Tissue samples were processed by FWRI's molecular genetics laboratory in St. Petersburg, Florida using DNA fingerprinting techniques and polymorphic microsatellite DNA markers identified for tarpon (Seyoum et al. 2007). We employed established statistical methods (Balding and Nichols 1994; Waits et al. 2001; Tringali 2006) to compute Bayesian posterior probabilities of individual identification (*PI*). For the present study, use of fixation-indices and other corrections to individual assignments were unnecessary because Atlantic tarpon genetically structured on much larger regional scales than that encompassed within our study area and because population levels of co-ancestry are very low (Tringali and Gray, unpubl. data).

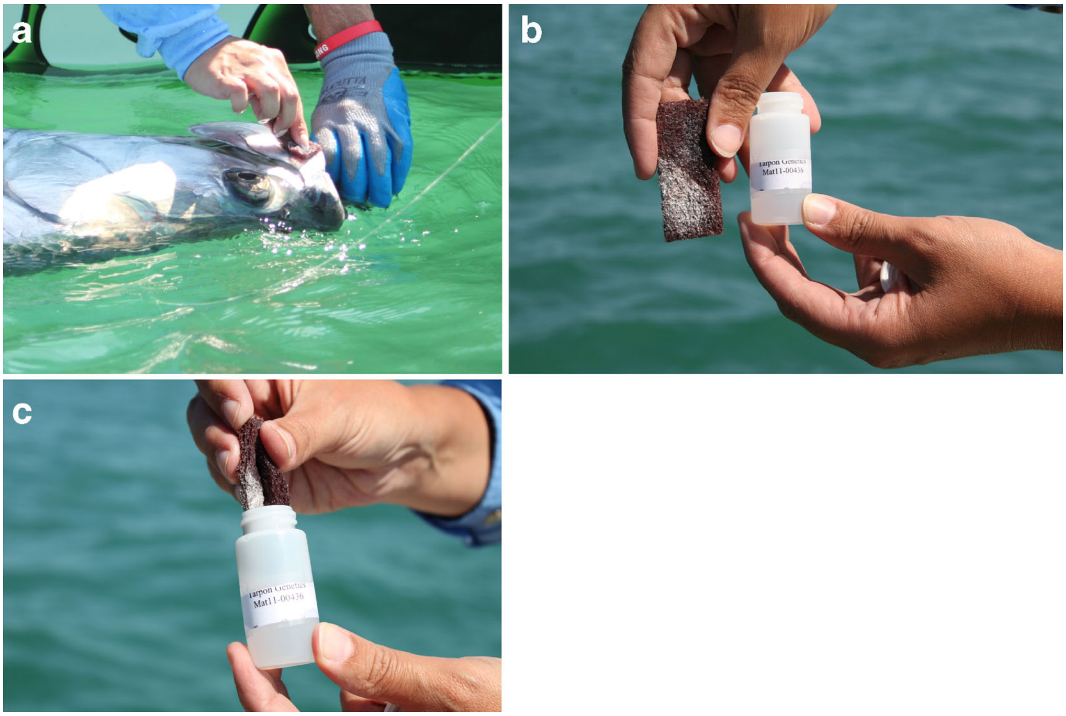

Fig. 2 The jaw scrape technique: **a** scrape the jaw to remove some skin cells; **b** ensure the abrasive sponge has silver tissue on it; **c** place the sponge with silver skin cells into the uniquely labeled vial filled with EtOH solution

However, study-wide adjustments for multiple surveys were employed (Evett and Weir 1998; Balding 2002).

Marketing, public relations, incentives

Project marketing, outreach efforts made by staff and project volunteers to the angler community, was imperative to educate the public on the importance of contributing DNA samples and associated capture information for biologists to gain a better understanding of the tarpon fishery. Educated anglers were more likely to become stakeholders in the study and help promote and contribute regardless of whether they ever caught a tarpon. Extensive outreach efforts were made targeting specialized groups of anglers at tarpon tournaments, local and specialized fishing clubs and at community events where staff distributed promotional and printed educational materials, sampling kits and presented seminars (Fig. 3). These efforts were invaluable in spreading awareness and encouraging anglers to participate in the study. Public outreach commenced in west central and southwest Florida where FWRI staff were in the field conducting active tarpon research and where both FWRI and MML headquarters are located. In 2010, specialized anglers of the Florida Keys were targeted to participate, followed by the East Coast in 2011, and the northwest and northeast parts of Florida in 2012 and 2013. Statewide outreach efforts including media involvement, mass emails to participants, and year-end newsletters were important to involve anglers, keep them informed of results, and to issue reminders of upcoming deadlines and general project announcements (Fig. 3).

Incentives were used to encourage new anglers to participate and reward anglers for their valuable contributions. The Angler Reward Program was a popular part

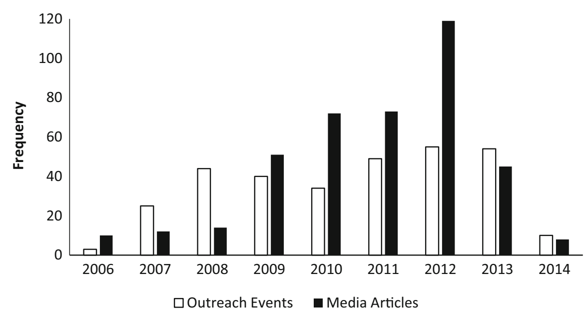

Fig. 3 A summary of public outreach events, including fishing tournaments, attended by staff and volunteers and known printed media articles about the tarpon genetic recapture study

of the study and was made possible by MML being a 501 (c) (3) non-profit organization that could solicit and receive in-kind donations. Donation volunteers and MML staff placed emphasis on acquiring donated items from local and national businesses for end of year annual angler rewards, bi-monthly angler awards, and for study promotions at angler events (e.g., gift baskets of angler items awarded at tournaments for the most samples submitted). Any angler submitting one sample was eligible for these randomly selected rewards. Other angler incentives, such as study decals, hats, and shirts, had to be earned by returning one, three and five tarpon samples, respectively. Entities that provided in-kind or cash donations to the MML Donation Office or Wildlife Foundation of Florida were sent a letter to acknowledge receipt and to thank them for their donation. Special Angler Challenge Promotions were also initiated by motivated and enthusiastic entities other than FWRI and MML, such as local guide associations, artists, individuals, local businesses and tournament sponsors. These groups/individuals created their own guidelines for their challenges and provided the reward(s). Recipients of rewards and challenge winners were called and congratulated and recognized in email blasts and annual newsletters. Personal gratitude was expressed to individuals and businesses by handwritten thank you cards sent to anglers and donating businesses, annual letters and emails of gratitude were provided to all participants whether or not they returned a sample, and a personalized "Certificate of Appreciation" was mailed to each participating shop. Finally, all anglers involved in a tarpon recapture event were mailed a map of their tarpon's catch locations and a letter containing all the known information at the time the recapture was identified.

Results

From the pilot study in 2005 through December 2014, the study received 24,572 tarpon DNA samples from volunteer citizen scientists (Figs. 1 and 4). Most of the samples (n=22,992) were collected from tarpon caught in Florida waters (Fig. 1b), 690 samples were returned from other states, totaling 23,682 samples from the southeastern United States (Fig. 1a). An additional 735 samples were returned from tarpon caught in other countries and 155 samples were returned from undisclosed locations. Florida sample summaries revealed that regionally DNA samples were returned from Gulf and Atlantic Coasts and Florida Keys each year since 2008. However, when broken down by counties, the fewest samples were returned from north Florida; Pasco county and northward on the Gulf Coast and from Volusia County and northward on the Atlantic Coast (Fig. 1b).

During the pilot year (2005), 32 anglers and staff contributed 177 samples (Fig. 4). In 2006, the study expanded statewide and angler participation and samples taken more than doubled. In 2007, the ease of the new sampling method combined with partnering with MML resulted in another doubling of DNA samples taken (Fig. 4). The study continued to grow each year until peaking in 2012 with 4,921 tarpon samples (Fig. 4). There was a slight decline in sample returns for 2013, and fewer still in 2014, the last year for sample collections. Not all anglers provided the date when a sample was taken (n=332).

Size information provided by anglers indicated that 500 or more juvenile tarpon and 1,000 or more adult tarpon were sampled annually since 2008 (Fig. 5). In 2012, more juvenile tarpon samples were collected than adult tarpon. Because of this, the 2013 marketing strategy changed to requesting that anglers only sample tarpon 30-in. or larger rather than requesting DNA samples from any tarpon. Numbers of juvenile tarpon samples decreased significantly in 2013 and 2014, while adult samples remained fairly constant from 2010 with a slight peak in 2011 (Fig. 5).

Over all tarpon sampled, the average heterozygosity observed for the 9 microsatellite DNA markers was 0.6764 and the average number of alleles was 10.222 (minimum=5; maximum=30). For all sets of DNA samples that exhibited matching genetic profiles (n=520), statistical assignments were sufficiently powerful for inference of individual identification (minimum PI >99.9996 %; mean PI=99.99999994 %). These recaptures will be used in future analyses.

Marketing and public relations were integral to this study's success. Pulses of samples returned from different areas of Florida varied each season and were correlated to where and when personal outreach efforts were made by staff. As many as 55 outreach events were attended by MML and FWRI staff and volunteers who distributed thousands of educational products (i.e., fact sheets, newsletters, brochures) each year, and the number of events attended remained fairly stable from 2008 to 2013 with a slight decline in 2010 (Fig. 3). These

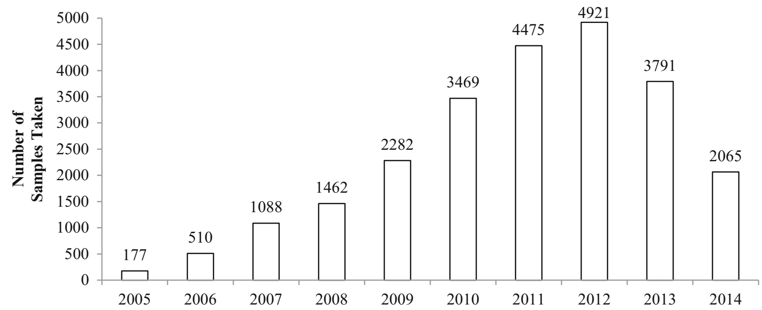

Fig. 4 An annual summary of the 24,240 tarpon DNA samples collected and returned by volunteer anglers. An additional 332 samples were returned with no date

totals included targeting species specific events, and each year since 2008 more than 22 tarpon tournaments incorporated some aspect of the study into their competition. Media communications also increased each year to a peak in 2012 through contributions made by reporters and outdoor writers (Fig. 3). Coincidentally, this peak in media coverage coincided with the year that most DNA samples were taken (Fig. 4).

Discussion

There were advantages of tracking tarpon with DNA. First, it was typically less costly than conventional tagging programs. tarpon DNA sampling kits were small, inexpensive to make, and once a tarpon's DNA was returned to FWRI's molecular genetics laboratory the in-house capability and professional expertise of staff made it cost-effective to process the samples. A 2011 cost analysis determined that creating one kit to sample three tarpon through the steps of processing one sample from start to finish in the laboratory cost \$3.10. This assumed no cost for distributing the kit or returning a sample. A second advantage was that obtaining a DNA sample was a less invasive way to tag tarpon than conventional methods which require an angler to insert plastic or metal tag anchors under a scale and into muscle or onto a pterygiophore. A small scrape of skin cells from the outside of the tarpon was all that was needed to extract enough DNA to genetically tag a fish. A limitation was that there were no experimental data to evaluate mucous loss or bacterial infection due to scraping skin cells from the jaw. Informal observations on genetically sampled tarpon held in captivity for several months as part of a physiology study in 2008 showed no discernable evidences of bacterial infection at the scrape sites, although two fish developed some pink discoloration at the scrape site. These two fish did not appear to develop any serious complications. There was also no work done to evaluate long term effects of the jaw scrape technique on tarpon health. A third advantage of the DNA scrape was that no batteries or technology were needed for the tagging method. The jaw scrape method as a way to monitor fish movement between two points was incidentally validated with pop-up satellite archival tag (PSAT) technology. A tarpon caught and genetically sampled off Sarasota during June 2010 was caught and sampled again in July 2010 off Islamorada and exhibited the same spatial and temporal movement pattern as another tarpon tagged with a PSAT from the

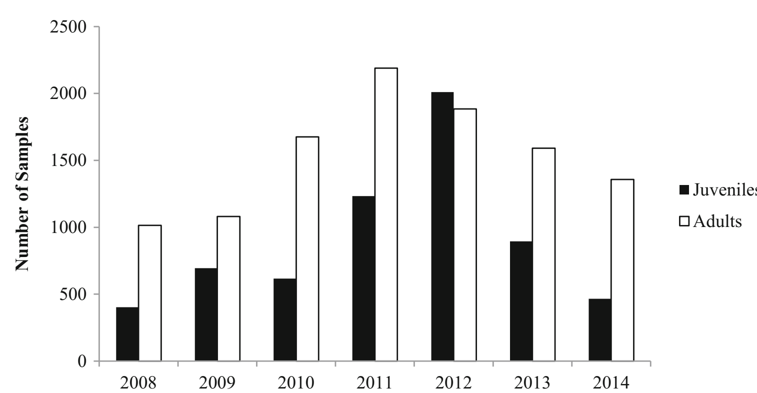

Fig. 5 The annual number of DNA samples returned from two life history stages (juvenile, adult) of tarpon from 2008 to 2014

University of Miami that same year (Ault pers. comm.). Finally, tarpon DNA served as a unique natural lifelong "tag" thus eliminating tag shedding as an issue found in other mark-recapture studies. One disadvantage to DNA sampling was there were no external markers which would immediately inform an angler that their caught fish was previously tagged, so anglers had to be aware of the existing study to participate. This added impetus to the importance of outreach in this type of citizen-based sampling design. Fortunately, the study gained local, state, national and international support from many individuals, organizations and media outlets that assisted greatly in performing their own outreach and contributing to media coverage for publicity.

There were several benefits of using citizen science in tarpon fishery research. The integration of a large number of volunteer citizen scientists was invaluable to this study by providing research data, that when pooled together, created an enormous body of scientific data for understanding patterns and trends of tarpon over a large geographic scale. Such a study would have been impossible if sampling had only been performed by researchers as the species is difficult and expensive to catch in great numbers. The study allowed stakeholders to interact directly with the tarpon resource to personally assist in learning about the tarpon fishery. This was not the first citizen-based tagging program targeting tarpon, but it was more efficient at tagging a large number of fish at a much broader scale than previous studies. Volunteers for NOAA had previously dart tagged 10,000 tarpon over the course of 40 years, whereas in this study citizen scientists were able to permanently mark and catalog DNA from more than 24,000 tarpon in 9 years.

Integrating volunteer anglers was a cost effective way of obtaining research samples and we had a moderate to high level of stewardship commitment from stakeholders (Granek et al. 2008). Anglers provided the in-kind services of their boat, equipment, fuel, and their time. There was little impact on the fishery since anglers sampled fish caught when recreationally fishing, although a few anglers modified their "normal" behavior when a sense of competition was involved. Regular service volunteers in the lab were invaluable in making DNA sampling kits, calling the shops monthly, sending out mailings, and soliciting items for angler incentives. The success of this collaboration of scientists and stakeholders was attributed to the outreach and education efforts made by staff and volunteers, and from publically posting the study's shared objectives and attainable goals (Wong-Parodi and Strauss 2014). Successful participation by citizen scientists was an opportunity for the stakeholders to increase their connections to science, place, and nature, while supporting science literacy and environmental stewardship (Bonney et al. 2009). Contact with staff was easily available to anglers directly via email, through phone calls, by using toll free numbers for kit requests where an actual person answered the phone during the day, and by having staff personally attend stakeholder meeting. Public seminars were also held in an effort to gain trust, a key component to successfully communicating science to the public and earning their respect and establishing the study's credibility (Fiske and Dupree 2014).

While not the first study to use DNA as a way of identifying individual fish, this was the first study to use DNA fingerprinting techniques as a successful tool for tracking individual tarpon. This provided an alternative method of collecting information on a catch-and-release species where no standard stock assessments to date had been performed to estimate population size, abundance, movement patterns or catchability (Pine et al. 2003; Adams et al. 2013). The jaw-scrape method has not been a typical approach of obtaining tissue samples from fishes, but was especially useful when dealing with tarpon, a large, powerful fish. This method could be applied in other mark-recapture and genetic studies on various fish species.

This was the first study of conducting a mark-recapture study using DNA as the marker at such a large geospatial scale in an open system with citizen scientists performing nearly all of the sampling effort. One study evaluating the effect of catch-and-release fishing on the reproductive success of Atlantic salmon also used DNA to genetically tag 268 adults and relied on volunteer anglers to return the DNA samples and corresponding capture information (Richard et al. 2013). Science staff caught and initially marked all fish via a tissue punch as the fish came through a fish ladder and into the river to spawn. Richard's et al. (2013) study was confined to a river system and the staff conducted the initial marking. Individual anglers were required to register their sampling kits. In our study, citizen scientists performed all of the sampling and staff only participated as recreational anglers on their own, if they so desired. In our study we did not require anglers to register sampling kits, because our study was broad-scale and kits were available at numerous venues. We did try to focus on providing sampling kits to specialized anglers who targeted tarpon.

We found that anglers who took the initiative to contact us directly or who followed up from an outreach event to request a kit, were more inclined to use the kit as compared to those who were simply provided with a kit at an event. Anglers who were serious about participating in the study generally were more apt to provide personal contact information at general outreach events.

Having a presence at public outreach events or on the water among recreational anglers resulted in increased participation and subsequently sample returns. This agrees with Richard's et al. (2013) study where staff were "consistently present on the riverbank promoting the project and assisting fishermen with DNA collections". As a result of that presence, Richard et al. (2013) had a high participation rate (42 of the 46 salmon captures were genetically sampled). Although we placed an emphasis on statewide tarpon DNA collections, we could not be ever-present in the field because of the spatial complexity of Florida's fishery. Awareness of the study was slow to spread to some coastal areas of Florida since staff travel was somewhat restricted. Recognizing this, we monitored the sample returns to see where we needed to increase our outreach efforts. During 2008, more than 1,500 tarpon DNA samples were taken (Fig. 4), but most were from the southwest Florida fishery, and few samples were returned from the Florida Keys, despite there being a year round fishery in the Keys. Therefore, in 2009, we emphasized our outreach efforts in the Ten-Thousand Islands off Collier County, and in the Everglades, Florida Bay and the Florida Keys, Monroe County (Fig. 1). As a result, anglers took more than 2,000 samples, which coincided with the sampling effort we wanted to achieve (Fig. 4). In 2010, presentations were given in the Florida Keys at several tarpon tournament captain meetings, at a guide association meeting, and to the Islamorada Fishing and Conservation Trust board. This resulted in MML being awarded a grant for promotion of the study in Monroe County during 2011. This grant enabled staff to have a greatly increased presence to meet with various groups and with guides and anglers at docks and marinas. By the end of 2010, Atlantic coast sampling remained about the same, but the Florida Keys sampling increased 88 %, and Gulf sampling increased 34 % bringing the total number of samples taken to 3,469 (Fig. 4). After the 2011 season, Keys sampling increased another 64 %. During 2011, staff also directed more effort into fishing club presentations, angler intercepts at docks, marinas, and boat ramps, and visits were made to every Atlantic Coast shop. The result was a 178 % increase in Atlantic Coast samples. Brevard County accounted for 20 % of the total returned samples in 2011, which was attributed to anglers catching and sampling many juvenile tarpon on fly. In 2012, the actual number of DNA samples peaked (Fig. 4) and samples from large, adult tarpon were surpassed by the number of juvenile tarpon sampled within the Indian River Lagoon system (Figs. 1 and 5), an area known for its tarpon nursery habitat (Harrington 1966; Poulakis et al. 2002; Jud et al. 2011). Because of the high proportion of juvenile tarpon samples returned in 2012, focus changed in 2013 with a minimum size requirement for tarpon sampled. Again, marketing with our annual newsletter, posters, and media communications successfully promoted this change. In 2013, there was a slight decline in sample totals (Fig. 4), which perhaps was the result of the political and social climate of tarpon management issues in Florida. Regulatory changes were being discussed and implemented and miscommunications made some lose trust in the research process. Also, by the end of 2013, it was announced that the study would be ending in 2014, that there would no longer be tournament involvement, and that we preferred DNA samples from fish more than 30-in. in length. We also shifted emphasis to collecting samples from fish caught in north Florida and recommended that anglers in other areas use their remaining sampling supplies. We presume that these circumstances contributed to the decline in the 2014 number of DNA samples.

Planned outreach visits to geographic areas were most productive when timed according to that region's fishery. Counties from northeast and northwest Florida continued to be areas with low sample returns, so we established more directed outreach events in those locations starting in 2012, already quite late in the study. North Florida was the last geographic area of the state that we targeted with personal outreach as the fishery is shorter in its annual duration and most anglers there do not target tarpon. We chose to use our limited travel resources to conduct outreach programs in areas of Florida with more tarpon and tarpon anglers. We learned through the dynamic process of conducting citizen science that a group of committed anglers needed to be established pre-season and continued personal involvement with them throughout the season or at least mid-season needed to be maintained to keep them engaged in the study. Even with our directed efforts, two visits per year were all we could cover in northeast and northwest Florida, and our visits typically did not coincide with the region's tarpon season. It also took about 2 years in any one location to establish and network a reliable group of participating anglers, but with the study ending in 2014 there was not sufficient time to establish this network in north Florida. We also found that many of the fishing guides along the northwest Florida coast were fly fishermen who, in general, preferred not to handle the fish long enough to take a DNA sample. It was not our intent to attempt to force or coerce anglers to change their fishing practices or go beyond their comfort level when handling a tarpon. One group of guides from Apalachicola chose to participate during 2006, the first year of our study, but were immediately turned off by the difficulty in trying to fin-clip a large, strong tarpon. It was their feedback that helped us to realize that a different method of obtaining tissue was necessary if the study was to succeed. By the time we were able to initiate the jaw scrape sampling method in northwest Florida, most of those same anglers were actively involved in other tarpon research programs.

Angler incentives did encourage some anglers to participate in the study, but were not the driving force for all anglers to participate. According to Pollock et al. (2001) it is a poor idea to conduct a tagging study with no reward to offer and that you need incentives. However, he cautioned that for multi-year studies “anglers may tire of the novelties.” To avoid this participation burnout, we added incentives so that anglers had to earn their shirts and decals. Decals featured our brand logo and were a different color each year and a different wildlife artist’s tarpon print was featured on the t-shirts making these collectibles. We held end-of-year lotteries in which each person who returned a sample was eligible one time regardless of the number of samples they returned. Pollock et al. (2001) recommended no end of year lottery, but rather to offer rewards during the year. This we did with bimonthly drawings eligible to anglers who returned a sample during those 2 months. Other specialized angler challenges were offered throughout the year as individuals and entities created them. This created a risk of anglers changing their behavior (Pollock et al. 2001) thus increasing their normal fishing pressure based on the incentives offered. For example, one angler already participating in the study at a lower level of effort single-handedly returned 975 samples from juvenile tarpon in response to a challenge offered in 2012. While we did witness such behavioral changes in a few cases, it was not common among anglers who returned samples. The use of visual tags with high dollar rewards has been evaluated as incentives for anglers (Murphy and Taylor 1991; Pollock et al. 2001), but we had no cash incentives. In fact, there were no visible tags used as cues to an angler that a tagging study was taking place. Most tarpon anglers were excited about participating in the project because of their passion for the fish. The promise of a letter containing information about any recaptured tarpon that would include a map of its catch locations and the promise of an end-of-year newsletter summarizing new study results were incentive enough for most anglers. Longtime tarpon fishermen possess a passion for their sport which is perhaps unparalleled by that for any other sport fishermen.

Overall, the tarpon Genetic Recapture Study was well received by anglers as indicated by the increased number of samples returned from year to year. The jaw-scrape method proved to be a novel, relatively easy and less invasive way to collect tissue samples from large, powerful fish, and the involvement of volunteer citizen scientists for sample collection permitted the study to cover a spatially complex fishery at a fraction of the cost. We recommend the following for a successful sportfish mark-recapture citizen science study: promote participation by targeting specialized audiences (anglers) and specialized events (fishing club meetings, tournaments) throughout the study area; make it easy and inexpensive for participants to obtain the desired data/sample and provide it back to the researcher; continuously implement marketing and public relations strategies to promote study awareness and public education; budget funds for staff and volunteer travel to be present in target areas during critical times (the fishery season); maintain open and honest communication with stakeholders to keep them informed of study objectives; use incentives to keep participants engaged; provide newsletters or study updates to keep participants involved and others interested in the study even if they do not collect data, to help spread study awareness and to show gratitude for their assistance.

Future work

Only DNA samples from tarpon released alive in Florida that were caught on hook-and-line will be used in the mark-recapture analysis. DNA collected from dead tarpon or tarpon caught by means other than angling (e.g., cast net or seines) will be omitted from mark-recapture analyses. Data obtained from tarpon identified as recaptures will provide insight and data to evaluate the following: recapture rates, expected ranges of movement during the course of a single spawning season (April through July, Crabtree et al. 1997) or offseason (August through March), linkages or connectivity, if any, between certain spawning and overwintering habitats/locations, and to determine if season-specific fidelity is exhibited to particular locations from 1 year to the next. Frequencies by range of movement for each recaptured tarpon within these categories will be generated and evaluated for emerging patterns of movement. Seasonal movement summaries will also be prepared for juvenile and adult life history stages. Life history stages assigned based on the length estimates provided by anglers will be used and analyzed separately to evaluate habitat preferences for juvenile tarpon and to determine if juvenile tarpon sampled within Florida nursery habitats during this study grow to supply the adult fishery.

The DNA samples cataloged from this study can be analyzed and applied in different ways to address other questions and objectives. For example, a new study commenced which will use the Florida data with new samples being collected from other states and international locations to perform a regional metapopulation analysis to evaluate stock structure of these spatially separated populations. Results should contribute to the development of effective management regimes for the species. While beyond the scope of the FWRI at this time, another project could utilize this study's samples in an effort to try and determine familial relationships among tarpon. Population genetic tools may provide staff with an ability to estimate population size for some localized areas of Florida where we have large sample sizes, such as certain areas of southwest Florida.

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Conflict of interest Six of seven authors declare that they have no conflict of interest.
Proceedings: publishing in the symposium proceedings.
Conflict: Guindon is a member of Bonefish & tarpon Trust, the organization that sponsored the symposium and proceedings. Guindon has received a grant from Bonefish & Trust for other work and the opportunity to travel in the past.
Statement on the Welfare of Animals: "This article does not contain any studies with human participants performed by any of the authors."
Several authors and many volunteer anglers contributed DNA samples to the study that were collected while recreationally fishing. To the authors' knowledge all tarpon fishing was routine practice within the recreational fishing sector and was in accordance with the state regulations as published by management staff.

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