

Management in Practice**Expert bioblitzes facilitate non-native fish tracking and interagency partnerships**

Pamela J. Schofield

U.S. Geological Survey, Wetland and Aquatic Research Center, 7920 NW 71st Street, Gainesville, FL 32653, USAE-mail: pschofield@usgs.gov

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OPEN ACCESS**Abstract**

Documenting the distribution and composition of non-native species populations can be challenging, especially when species cross jurisdictional boundaries that require interagency coordination. Herein I report the development of three tools that have been used in Florida over the past seven years to assist with tracking of non-native fishes: 1) an overarching organization to increase coordination and communication amongst stakeholders (Florida Non-Native Fish Action Alliance); 2) regularly-scheduled expert bioblitzes (Fish Slams); and 3) symposia (Fish Chats). Ten Fish Slams were held since 2012, which have included nearly 100 individuals from 20 organizations. Participants have sampled nearly 200 unique sites, capturing 36 non-native fish taxa. These activities have generated over 600 records for the U.S. Geological Survey's Nonindigenous Aquatic Species database. Many specimens collected during Fish Slams are deposited into natural history museums or used by researchers. Informal interactions amongst colleagues working together in the field, at check-in meetings at the end of the day, and during more structured Fish Chat symposia allow members of various organizations to become acquainted, build trust, and share information and technology, which may then lead to professional collaborations. While this program is focused on non-native fish species in south Florida, I also discuss how the expert bioblitz may be adapted to suit other taxonomic groups and a variety of conservation needs.

Key words: bioblitz, non-native fishes, interagency cooperation

Introduction

Documenting the identities and distributions of introduced species is foundational to biological and ecological research, impacts assessments, and development of effective management strategies. However, in rapidly-changing systems, it is often a struggle to acquire these most basic data. Bioblitzes, originally developed to highlight native biodiversity, increasingly are used to search for and document non-native species (e.g. Meshaka et al. 2008; Cohen et al. 2011). Herein, I report on a program that was developed to increase documentation of non-native fish distributions using bioblitzes in Florida, USA.

More than 160 non-native freshwater fish species have been documented in Florida, and at least 34 of those are established (i.e. reproducing; Schofield and Loftus 2015; USGS-NAS 2019). Based on past introduction histories, about seven new species become established each

decade (Schofield and Loftus 2015). Non-native fishes occupy waters in federal, state, county, and tribal jurisdictions as well as private property. Distributions are tracked by the U.S. Geological Survey's Nonindigenous Aquatic Species database program, which is publicly available online (USGS-NAS 2019). However, the database serves solely as a data repository for information provided by others; there is no active sampling program associated with it. Resources and priorities vary widely among the numerous jurisdictions, which has created a patchwork of effort across the landscape. For example, some jurisdictions are regularly and thoroughly sampled, like Everglades National Park, where a decades-long monitoring program tracks fish distributions and community changes (e.g. Trexler et al. 2005; Kline et al. 2014). However, many water bodies in the state are not sampled on a regular basis.

In this report, I describe a program that has increased documentation of freshwater non-native fish community composition and geographic ranges in Florida. A group was formed (Florida Non-Native Fish Action Alliance; FNNFAA 2019) that draws on scientific expertise from multiple organizations to collect distribution data on non-native fishes through bioblitz-type field days. Another benefit of the group is the facilitation of communication amongst members, which has led to stronger partnerships and research collaborations. The program developed in Florida and the benefits derived from it are presented here as an example of how regional interagency coordination can be leveraged inexpensively to collect biological data in the absence of formal sampling programs. I also discuss alternative adaptations of the expert bioblitz to suit a variety of conservation needs.

Materials and methods

Fish Slams

Bioblitzes are traditionally used to rapidly document the biodiversity of a specific area, include multiple taxonomic groups, and engage the public (e.g. Karns et al. 2006). I use a modified model that includes only experts who target one faunal group: non-native fishes. Parker et al. (2018) called these types of events “expert bioblitzes”. Bioblitzes are not a substitute for formal monitoring programs but may provide valuable information in their absence. The use of expert bioblitzes in Florida has evolved over time, beginning with the finding of an “extirpated” species.

In 2012, several specimens of non-native croaking gourami *Trichopsis vittata* (Cuvier, 1831) were collected near Arthur R. Marshall Loxahatchee National Wildlife Refuge in Palm Beach County, Florida by a U.S. Fish and Wildlife Service employee (D. Pecora). This species had not been collected in over 15 years and was considered extirpated. Realizing it was still present, a small group of researchers from a few agencies converged on the

location to document the current geographic range of *T. vittata*. We collected many individuals, including juveniles and adults, and determined that *T. vittata* was reproducing (i.e. was established) but that it had a relatively small geographic range (Schofield and Pecora 2013). Additionally, during the one-day sampling event we collected a Jack Dempsey cichlid *Rocio octofasciata* (Regan, 1903), which was not previously known from the area. Subsequent collections by biologists from the Florida Fish and Wildlife Conservation Commission (FWC) revealed additional localities in the same area for *R. octofasciata* (K. Gestring, FWC, pers. comm.).

The success of the small interagency working group and the surprise finding of *R. octofasciata* spurred our group to consider future bioblitz-type field days, which we called Fish Slams. The Florida Non-Native Fish Action Alliance was formed in 2012 to serve as a central organization for communications and logistics (FNNFAA 2019). Our colleagues at the FWC provided input on priority sampling locations. We also coordinated with the Everglades Cooperative Invasive Species Management Area (ECISMA 2019). Stakeholders invited to participate included natural resource managers, fish biologists, museum scientists, university professors, and graduate students. Participants came from state, federal and municipal governments, non-profit/non-governmental conservation organizations, universities, museums, Native American tribes, and zoos. Participation was limited to professionals in the field who have their own sampling equipment and operate with minimal guidance. We have not engaged citizen scientists; however, it may be possible to do so in the future.

The first Fish Slams were held in Miami-Dade, Broward, and Palm Beach counties (hereafter “south Florida”), which is home to a large number of freshwater non-native fishes. Over time the geographic scope was expanded to include Big Cypress National Preserve in Collier and Monroe counties (March 2017), Indian River/St. Lucie counties (March 2019), and Orange/Seminole County (June 2019). We are planning to sample in Hillsborough and Manatee counties in 2020. By expanding the geographic scope of the events, we have added new members from the various areas, increasing the reach of our communications and potential collaborations.

The original goal of Fish Slam events was simply to survey for non-native fishes, especially in areas not regularly sampled. Over time, those goals have expanded to include:

- 1) Sampling water bodies (such as ponds, ditches, and canals) not normally sampled by biologists to document the non-native fish fauna. We look for species that are new to the aquatic community as well as changes in species distributions (e.g. range expansions).
- 2) Vetting unconfirmed reports of newly-introduced species or range-expansions of established species. USGS and FWC receive reports of new introduced species from online reporting platforms (e.g. USGS-NAS

sighting report 2019; EDDMapS 2019) and communications from our colleagues. To verify those reports, we sample the area from which the species was reported to try to confirm the new introduction. If confirmed, areas around the new introduction site are sampled to determine if populations are established and/or spreading. If feasible, eradications of new species are discussed, planned, and executed.

- 3) Providing up-to-date distributional information on freshwater non-native fishes to natural resource managers tasked with managing non-native species in their jurisdiction. We sometimes receive requests from natural resource managers to sample in specific locations and report back to them on the species composition of non-native fishes. For example, we were invited to sample in Big Cypress National Preserve in 2017, where fish surveys had not occurred for more than ten years (Zokan et al. 2015).
- 4) Providing data to the USGS-NAS database, which is the national repository for distribution data for aquatic non-native species. It is publicly accessible online and includes distribution maps as well as biological and ecological information for each species.
- 5) Providing specimens to natural history museums. The primary museum partner is the Florida Museum (formerly Florida Museum of Natural History; FMFC 2019); however, staff from several other museums have joined our events. Specimens deposited at museums are available for study by academics in perpetuity. Data on fishes housed at most modern natural-history museums are available publicly online.
- 6) Providing specimens directly to academics, graduate students, and fish biologists for use in research projects.
- 7) Bringing together stakeholders from disparate jurisdictions and management philosophies to increase communication and facilitate partnerships.

At this time, Fish Slams have a relatively narrow focus – non-native fishes. However, in the future, it is possible to expand this to include other faunal or floral groups (e.g. invertebrates, plants). We have included a botanist on two events so far and would like to expand this capacity to include more individuals in future events.

Steps involved in conducting a Fish Slam include:

- 1) Preparation – The field coordinator surveys potential sampling sites, considering various factors such as accessibility (e.g. presence of boat ramps), the length of time elapsed since the site was sampled, unconfirmed reports of newly-introduced non-native fishes, and areas that are hot-spots for introductions. The field coordinator also integrates

requests from stakeholders, such as natural resource managers that would like to know what non-native fishes are in adjacent jurisdictions. For our events, personnel from the FWC, which is the primary State management agency, served as field coordinators for all Fish Slams except one (Indian River and St. Lucie counties 2019). The communications coordinator (Schofield) schedules the dates, obtains sampling permits from FWC, invites stakeholders, tracks who will be attending and what gear they will bring, and groups participants into either boat or ground crews (2–5 people per group). Boat electroshocking is a common technique to survey for non-native fishes in Florida but can only access navigable waterways. Ground crews operate from trucks and work at non-navigable sites with seines, dip nets, backpack electroshockers, hook-and-line, and minnow traps. Each group has a designated data collection lead (i.e. the person that will be responsible for filling out data sheets). We also make sure there is at least one taxonomic expert per group who can answer fish identification questions as they arise in the field.

- 2) Day 1 – We begin with a morning meeting, wherein each group is given their field assignments, data sheets, directions to sites, and copies of the scientific collection permit. All groups are provided with the mobile phone number of the communications coordinator in case they have questions or require assistance throughout the day. Groups are then released to fish on their own all day and report back to the check-in meeting in the afternoon. Sampling is not quantitative; we only record species lists for each location. A subsample of fishes captured is retained and brought to the check-in location for positive identification. At the afternoon check-in, each group's data sheets are collected and checked for completeness, fish specimens are photographed for USGS-NAS records and then processed by museum personnel, and Day 2 field assignments are distributed.
- 3) Day 2 – Fishers proceed directly to their field assignments (i.e. no morning meeting) where they are again on their own to sample until the afternoon check-in meeting.

Many of the fish specimens brought to the afternoon check-in meetings are preserved by museum personnel. Any leftover fish carcasses are donated to local zoos and farms, where they are used as animal feed or fertilizer.

Fish Chats

Before the FNNFAA was created, our colleagues at the FWC had been hosting single-day symposia (Fish Chats) where regional fish biologists gave presentations on current projects and results from recently-completed monitoring or research activities. It was a natural fit to combine this activity with the Fish Slams, and we began doing so regularly.

Table 1. Summary statistics for Fish Slam events held throughout Florida (2012–2019). Fish species refers to number of non-native taxa captured or observed. USGS-NAS = U.S. Geological Survey’s Nonindigenous Aquatic Species database. Museum lots include Florida Museum, Virginia Museum of Marine Science, Florida Atlantic University teaching collection and Yale Peabody Museum of Natural History.

Date/Location	Sites	Fish species	Range expansions/surprises	USGS-NAS records	Museum lots	Participants	Agencies
8 Nov 2012							
In and around ARM Loxahatchee National Wildlife Refuge	13	9	<i>Rocio octofasciata</i>	33	31	14	5
20 Nov 2014							
Miami-Dade County	16	16		66	17	18	5
3 Nov 2015							
Broward County	9	10		37	5	13	5
25 May 2016							
Broward and Miami-Dade counties	12	22	<i>Hypostomus plecostomus</i> , <i>Trichromis salvini</i>	54	40	20	7
1–2 Nov 2016							
Palm Beach, Broward, and Miami-Dade counties	20	21	<i>Monopterus</i> sp. c.f. <i>albus</i>	84	9	22	8
22–23 Mar 2017							
Big Cypress National Preserve	28	13	<i>Oreochromis niloticus</i>	34		25	9
7–8 Nov 2017							
Broward and Miami-Dade counties	35	20	<i>Macrogathus siamensis</i>	99	62	32	11
6–7 Nov 2018							
Palm Beach, Broward and Miami-Dade counties	22	23	<i>Cyprinus carpio</i>	117 + 3 botanical	176	32	11
26–27 Mar 2019							
Indian River and St. Lucie counties	18	12	<i>R. octofasciata</i> , <i>Xiphophorus hellerii</i> , <i>X. maculatus</i>	56 + 3 botanical	40	30	10
5–6 June 2019							
Orange and Seminole counties	22	10	<i>Cyprinus carpio</i>	29	10	17	4

Results and discussion

Fish Slams – Summary statistics

Ten Fish Slams were held from 2012 to 2019 spanning nine Florida counties (Table 1; Figure 1). Nearly 100 individuals from 20 organizations have participated, with some experts having attended every event, while others only participating when events are held in their geographic region. Participation has increased as the program became better-known. Participating organizations include:

Federal/State/County government: U.S. Fish and Wildlife Service, U.S.

Geological Survey, U.S. Army Corps of Engineers, U.S. National Park Service, Florida Fish and Wildlife Conservation Commission, St. Lucie County Environmental Resources Department, City of Winter Park

Universities: University of Florida, Florida International University, University of Tampa, University of West Florida, Broward College

Natural history museums: Florida Museum at University of Florida, Nunnally Ichthyology Collection at Virginia Institute of Marine Science, Florida Atlantic University teaching collection, Yale Peabody Museum of Natural History.

Native American tribes: Miccosukee Tribe of Indians of Florida

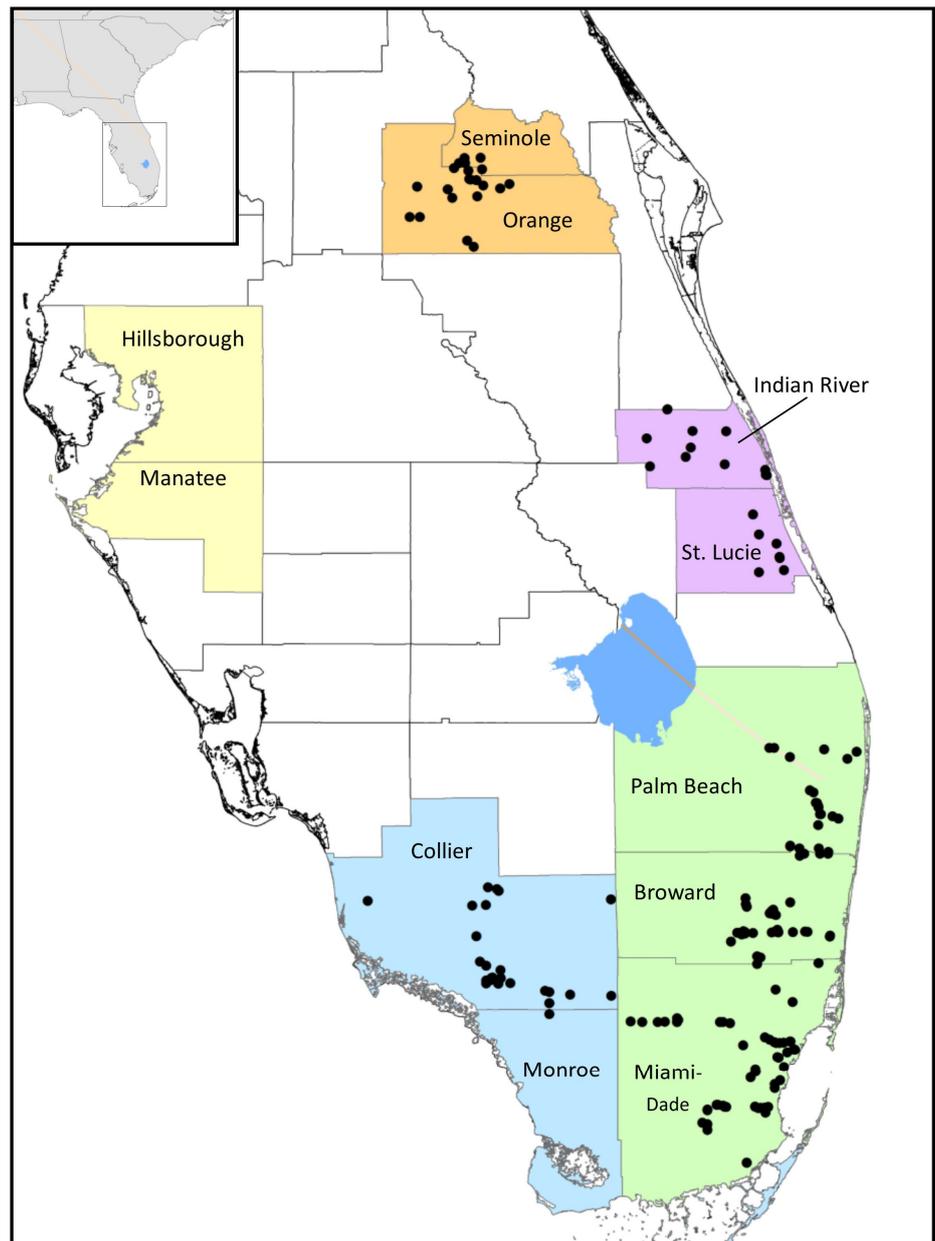


Figure 1. Sampling locations for ten Fish Slam events (2012–2019). Counties shaded in green were sampled from 2012–2019; blue in 2017; purple and orange in 2019. Sampling in counties shaded in yellow is being planned for 2020.

Non-governmental organizations/other: Deering Estate, Audubon Florida, Zoo Miami

The first four Fish Slams were one-day events. Over time, Fish Slams were expanded to two, two-day events per year. As the program grew and participation increased, the work involved in coordinating events subsequently expanded, and Fish Slams are now regularly scheduled each year for Spring and Fall and planning begins about six months before each event. By establishing a regular schedule, stakeholders anticipate the events each year, making it easier for them to fit our events into their schedules and thereby increasing participation. In 2019, we added a Summer “mini-slam”, in which only a few agencies coordinated sampling in a local area.

Because there were fewer participants and sampling locations, as well as reduced travel, we were able to plan and execute the mini-slam in a matter of weeks.

As participation increased over time, more field teams were available at each event to sample more locations. To date, up to 10 field teams have been dispatched to work simultaneously. One hundred and ninety unique locations have been sampled (Figure 1), including a variety of habitats, both man-made and natural (canals, ponds, lakes, retention ponds, ditches, rivers, etc.). Several locations were sampled more than once, as we frequently found new fish introductions presumed to be aquarium releases.

Thus far, we have collected or observed at least 36 non-native fish taxa (Table 2). Non-native fishes in Florida have myriad taxonomic difficulties, and many species identifications are provisional. Furthermore, hybridization of feral populations adds to taxonomic confusion. For detailed information on taxonomic issues of Florida non-native fishes, see the review by Schofield and Loftus (2015). Only non-native fishes were collected; native species were either avoided during sampling or immediately returned to the water. Concurrent with the provisions of our FWC sampling permits, two non-native species were immediately returned alive: grass carp *Ctenopharyngodon idella* (Valenciennes, 1844) and butterfly peacock cichlid *Cichla ocellaris* Bloch and Schneider, 1801. Non-native fishes were most species-rich in southern Florida, where up to 22 taxa were collected (May 2016, November 2018). Most of those were cichlids (Family Cichlidae; Table 2). Fewer species were collected in Orange/Seminole counties (n = 10) and Indian River/St. Lucie counties (n = 12).

Six hundred and nine non-native fish records have been added to the USGS-NAS database from Fish Slam activities along with six botanical records. Three hundred and ninety museum lots have been catalogued at three natural history museums (Table 1). Seven additional uncatalogued lots were placed in a university teaching collection at Florida Atlantic University. Most fish specimens were fixed in formalin, preserved in alcohol, then archived as whole wet specimens. Fin-clip samples for future DNA analyses were collected from many of the specimens before they were preserved. Some specimens were frozen and later processed for skeletal collections.

Specimens collected at Fish Slams have been used by graduate students for research projects, including documenting diet habits of *Macrogathus siamensis* (Günther, 1861) (Florida International University) and population genetics of *Belonesox belizanus* Kner, 1860 (University of Tampa). Data from Fish Slams have also been used for species-distribution modelling.

Florida regularly experiences severe weather, including hurricanes, and flooding conditions can allow non-native fishes to access new locations. In the future, Fish Slams could be organized to quickly survey for changes in fish distributions after a severe weather event.

Table 2. List of non-native freshwater fish species collected or observed in Fish Slams. * Some fish identified as *Oreochromis aureus* may be hybrids with *O. niloticus*.

Family/Species	Common name	November 2012	November 2014	November 2015	May 2016	November 2016	March 2017	November 2017	November 2018	March 2019	June 2019
Notopteridae											
<i>Chitala ornata</i>	clown knifefish				x						
Clupeidae											
<i>Dorosoma petenense</i>	threadfin shad										x
Cyprinidae											
<i>Cyprinus carpio</i>	common carp		x		x				x		x
<i>Ctenopharyngodon idella</i>	grass carp		x	x	x	x		x	x		x
Serrasalminidae											
<i>Colossoma macropomum</i>	black pacu/tambaqui							x			
Callichthyidae											
<i>Hoplosternum littorale</i>	brown hoplo	x				x	x	x	x	x	x
Loricariidae											
<i>Hypostomus plecostomus</i>	suckermouth catfish				x	x			x		
<i>Pterygoplichthys</i> spp.	sailfin catfish	x	x	x	x	x	x	x	x	x	x
Clariidae											
<i>Clarias batrachus</i>	walking catfish	x	x	x	x	x	x	x	x	x	x
Poeciliidae											
<i>Belonesox belizanus</i>	pike killifish				x		x	x	x		
<i>Xiphophorus hellerii</i>	green swordtail									x	
<i>Xiphophorus maculatus</i>	southern platyfish									x	
Synbranchidae											
<i>Monopterus</i> sp. c.f. <i>albus</i>	Asian swamp eel		x		x	x		x	x		
Mastacembelidae											
<i>Macrogathus siamensis</i>	spotfin spiny eel							x	x		
Cichlidae											
<i>Amphilophus citrinellus</i>	Midas cichlid		x			x			x		
<i>Astatotilapia calliptera</i>	eastern happy								x		
<i>Astronotus ocellatus</i>	oscar		x		x	x	x	x	x		
<i>Cichla ocellaris</i>	butterfly peacock bass		x	x	x	x	x	x	x		
<i>Cichlasoma bimaculatum</i>	black acara		x			x	x	x	x		x
<i>Cichlasoma urophthalmus</i>	Mayan cichlid	x	x	x	x	x	x	x	x	x	
<i>Hemichromis letourneuxi</i>	African jewelfish	x	x	x	x	x	x	x	x	x	x
<i>Heros severus</i>	banded cichlid					x		x			
<i>Labeotropheus fuelleborni</i>	blue mbuna				x	x					
<i>Oreochromis aureus</i> *	blue tilapia	x	x	x	x	x	x	x	x	x	x
<i>Oreochromis mossambicus</i>	Mozambique tilapia				x						
<i>Oreochromis niloticus</i>	Nile tilapia		x			x	x			x	x
<i>Parachromis managuensis</i>	jaguar guapote		x		x	x	x	x	x		
<i>Petenia splendida</i>	bay snook				x	x					
<i>Rocio octofasciata</i>	Jack Dempsey	x								x	
<i>Sarotherodon melanotheron</i>	blackchin tilapia									x	
<i>Tilapia buttikoferi</i>	hornet tilapia		x		x			x	x		
<i>Tilapia mariae</i>	spotted tilapia	x	x	x	x	x	x	x	x	x	
<i>Trichromis salvini</i>	yellowbelly cichlid			x	x			x	x		
<i>Vieja melanura</i>	redhead cichlid				x	x					
Osphronemidae											
<i>Trichopsis vittata</i>	croaking gourami	x									
Channidae											
<i>Channa marulius</i>	bullseye snakehead			x	x	x			x		
Total		9	16	10	22	21	13	19	22	12	10

Surprise catches, range expansions, eradications

A few species were collected that were either unknown from the area or had not been collected in many years. As mentioned earlier, the first event

(2012) resulted in the collection of a specimen of *R. octofasciata* that later led to the finding of a small local population. Interestingly, a single specimen of *R. octofasciata* was also collected in the Indian River/St. Lucie Fish Slam in 2019. A reproducing population of this species was recently documented in Tampa Bay area of Florida (Lawson et al. 2017). However, it is unclear how widespread this species is in Florida, what the source of the introductions is, and whether populations are established. Additional sampling may help determine its range and population status.

Two species of *Xiphophorus* were collected during the Indian River/St. Lucie Fish Slam. Those are the first collections of *Xiphophorus* spp. in that area since the 1970s (Courtenay et al. 1974), and it is unclear whether they represent populations that have remained in place over the decades (similar to *T. vittata*; Schofield and Pecora 2013) or whether they were recently introduced.

In 2018 we captured one large (64 cm total length) *Cyprinus carpio* Linnaeus, 1758 from a canal in Broward County. That specimen was olive green, similar in color to wild-type carp. *Cyprinus carpio* is common in most freshwater habitats of the continental USA, and has been introduced world-wide; however, it is rare in south Florida. In 2019 we captured seven large *C. carpio* from a single lake in Orange County. None of the Orange County specimens were wild-colored; they were all mottled orange and white, (i.e. “fancy-colored” koi), leading us to believe they were releases. All fish were large adults (ca. 60–70 cm total length). No small individuals or wild-colored fish were observed or captured after extensive searching. Thus, we do not believe the population was reproducing, but will continue to follow-up with future sampling.

Range expansions were documented for several species in south Florida, including *Hypostomus plecostomus* (Linnaeus, 1758), *Trichromis salvini* (Günther, 1862), *Monopterus* sp. cf. *albus* (Zuiew, 1793), *Oreochromis niloticus* (Linnaeus, 1758) and *Macrogathus siamensis*. Those species likely used the extensive canal systems of south Florida to expand their geographic ranges and will likely continue to do so.

In 2014, a non-native cichlid (*Petenia splendida* Günther, 1862) was reported from a municipal park in Miami. It was an important find because the species was in a relatively confined area and appeared not to have spread into the interconnected canal system. That site was repeatedly visited during several Fish Slams to confirm the limited distribution of *P. splendida* and attempt to control its population. The work done during Fish Slams led to an offshoot project that eventually concluded with the eradication of *P. splendida* and another non-native cichlid (*Labeotropheus fuelleborni* Ahl, 1926) before they were able to spread from the site (Schofield et al. 2019).

Fish Chats

Since the inception of the FNNFAA, we have met for four Fish Chats (2014, 2016, 2018, 2019). Fish Chats are often held the day before Fish Slams, to capitalize on the gathering together of regional experts. The meetings are one-day symposia in which participants present 15-min talks with 5 min after each for discussion. Sometimes an hour or two is blocked off for group discussion on a particular topic of interest. For example, at the 2018 Fish Chat there was a group discussion on the use of environmental DNA to sample for non-native fishes. Researchers have discussed their ongoing projects or those they have recently completed, natural resource managers have briefed the group on monitoring and management activities, and graduate students have received feedback on their proposed research projects.

Social benefits of improved interagency cooperation

The social aspects of field sampling programs are not often considered; however, research and management benefit by building stronger ties amongst organizations and agencies that are facilitated by expert bioblitzes (Parker et al. 2018; Lowman et al. 2019). By increasing networking opportunities, communications, and trust amongst stakeholders, individuals have a wider array of tools and potential colleagues/advisors to draw upon.

Members of stakeholder organizations that participate in Fish Slams sometimes have disparate or conflicting missions. For example, a particular non-native fish may be considered a scourge to conservation by some while being considered a valued game fish by others. Conflicts such as these could hamper partnerships by creating animosity and distrust. However, the focus of Fish Slams is on a rather pragmatic and narrow scope (i.e. determining what non-native fish species are present at specific locations), which is seen as useful information by all regardless of management philosophy. By concentrating on that point of intersection, the FNNFAA is able to serve as an umbrella organization to bring professionals together and increase communication. Informal interactions amongst colleagues working together in the field, at check-in meetings at the end of the day, and during Fish Chats allow members of various organizations to become acquainted, build trust, and share information and technology, which may lead to professional collaborations.

Most Fish Slam participants are on-the-ground fish biologists or natural resource managers that regularly work outside in the field. However, we have also hosted managers and administrators who do not normally participate in field activities. It can be valuable for those folks to witness first-hand the work of field personnel in their agencies as well as other groups. It also gives them a more complete perspective on the habitats and fishes they manage. Retired biologists also enjoy joining in, either by

participating on the field teams or meeting up with the group at the afternoon check-in meetings. By maintaining contact with these individuals, their knowledge and historical perspective is used and retained over time.

We have worked with media personnel during Fish Slam events and benefited from their ability to spread awareness of issues of non-native species to the public (e.g. Staletovich 2017). Sometimes reporters accompany us on field crews; other times they simply meet with the groups at the check-in meeting. As we often sample in urban areas, we regularly engage with curious members of the public, which provides opportunities for education about non-native species.

Networking amongst the group has been very beneficial. Graduate students may discuss their work, either informally or in a more structured format in a symposium, allowing agency personnel to get to know them and their work. It is also a good way for students to learn about upcoming job opportunities. Career employees also benefit from a broader range of contacts, and relationships formed during Fish Slam activities have led to new research projects, technical innovations, invitations to serve on review panels, advice on ongoing projects, and many other partnerships and collaborations.

Adapting the expert bioblitz to serve a variety of conservation objectives

As detailed above, I have used narrowly-focused expert bioblitzes to collect distribution data on non-native fishes in Florida and increase interagency cooperation and communication. This is but one example of the many ways an expert bioblitz can be used for a particular application. Parker et al. (2018) reviews the many types of events that can be used to collect data (rapid assessments, bioblitzes, etc.). Factors to consider when developing an expert bioblitz program include:

Objectives: Expert bioblitzes and similar programs have been used to obtain data on rare species, archeological records, discovery of new invasions, novel associations of flora and fauna, and follow-up on decades-old data (Parker et al. 2018). A wide variety of taxa have been documented in single-taxa-focus events such as our Fish Slam and others examining arthropods, herpetofauna, or small mammals (e.g. Meshaka et al. 2008; Foster et al. 2013; Parker et al. 2018). More comprehensive bioblitzes include a diversity of taxa, such as Lowman et al. (2019) who surveyed an entire forest diurnally and nocturnally, including microbes, algae, tardigrades, arthropods, plants, and birds.

Habitat diversity: While we are able to sample almost all freshwater aquatic habitats in Florida with either boat or ground crews, different environments will require appropriate expertise. For example, Lowman et al. (2019) carried out a whole-forest survey in Malaysia that spanned from

soils of the forest floor to the uppermost tree canopy, requiring expert tree climbers. Individuals representing lands that are difficult to access can be invited to participate in expert bioblitzes, thereby facilitating data collection in areas not normally surveyed.

Volunteer pool: The original concept of the bioblitz was one that engaged citizen scientists and focused on public education (Parker et al. 2018). Citizen-science programs have proliferated over the past few decades and have expanded to include focused data-collection for natural resource management. In fact, some well-designed efforts have been shown to be more effective than professional scientific ones. For example, citizen scientists surveying lionfish (*Pterois volitans* [Linnaeus, 1758] and *P. miles* [Bennett, 1828]) off Florida detected the invasive species earlier and more frequently than traditional fishery-independent surveys (Scyphers et al. 2015). Thus, depending on the objectives of the bioblitz, the inclusion of citizen scientists may be useful. For Fish Slams, we limit the volunteer pool to fishery professionals, primarily because we work on electrofishing boats, a sampling method not suitable for the untrained public. Furthermore, expert bioblitzes may be enhanced by including both local professionals and national/international ones (Lowman et al. 2019).

Leadership and assigned roles: For Fish Slam events, we have a communications coordinator responsible for logistics and a field coordinator responsible for choosing and prioritizing sampling sites. Both of these positions require significant work prior to the event. The communications coordinator invites volunteers to participate, secures scientific collecting permits, and organizes the volunteers into groups. Individuals from diverse agencies are sometimes grouped together to facilitate communication. One person in each group is designated as the data recorder. We record data on paper data sheets; however, there are a number of digital applications available that could be useful in this context (Adriaens et al. 2015). We also make sure there is at least one taxonomic expert in each group to answer fish identification queries in the field. Most Fish Slam participants are familiar with the common taxa; the expert is needed when an unusual or rare specimen is collected. The field coordinator is responsible for making a list of field sites to be sampled and then designating which teams will visit which sites. Sometimes this requires the field coordinator to visit the potential sites before the event to ensure there is appropriate access or that water levels are sufficient for sampling. When needed, the field coordinator also contacts organizations such as municipal parks and homeowner associations to request permissions for access. The field coordinator integrates requests from local stakeholders. For example, a natural resource manager may have an interest in determining which non-native fishes are present just beyond the borders of their park. Alternately, museum scientists or graduate students may request collections of specific taxa for a research project. This pre-event work is done to

ensure that the volunteers can focus as much of their time as possible on data collection during the relatively short (two-day) event. However, all those steps may not be necessary to lead a bioblitz in, for example, a contiguous area without diverse patchworks of jurisdictional boundaries.

Cost: The Fish Slam program began as a small unfunded project, wherein each organization volunteered the use of their equipment and salary/travel costs for their personnel. As the project grew over time, I was able to secure funding from the USGS, which is used to pay for salaries of USGS personnel that coordinate the event and invitational travel for volunteers that do not have access to funds from their institutions to attend (e.g. graduate students). Funding has also been used to acquire multiple sets of fishing gear that can be loaned to volunteers who want to participate but do not have their own gear. Some agencies that have specifically requested us to work on lands they manage have covered the cost of hotel rooms for the group, which thereby increases participation and thus the amount of the data that we are able to provide.

Fish Slam events are two days in duration and include approximately 40–60 individuals. Travel costs for 10–20 participants are covered with USGS funding, equaling about USD\$10,000 to \$15,000 per Fish Slam, not counting salary and equipment costs. Lowman et al.'s (2019) comprehensive Malaysian expert bioblitz lasted ten days, included 117 participants, and cost USD\$100,000.

It is generally less expensive and faster to obtain data from expert bioblitzes than the traditional research model of writing a proposal, finding funding for the proposed project, hiring personnel, and then carrying out a survey. The data obtained from bioblitzes can be coarse – in our case, a species list for each location. Thus, it is important to consider the utility of the data when planning a bioblitz. For Fish Slams, even the simple data we collect is useful to natural-resource managers, especially in cases where there was no information previously available to them regarding the non-native fish community in their area. Furthermore, depending on the taxa surveyed and its ease of detection, bioblitzes sometimes provide data equivalent to traditional surveys (e.g. Foster et al. 2013).

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Ethics and permits

This study complies with institutional policies governing the humane and ethical treatment of experimental subjects. Permission to sample fishes was provided by the USGS/WARC Institutional Animal Care and Use Committee; IACUC Number: USGS/WARC/GNV 2018-08. Barron Moody and Ryan Hamm (FWC), and Steve Schulze (Big Cypress National Preserve) coordinated our sampling permits. Data associated with this manuscript may be accessed: <https://doi.org/10.5066/P9ZKZLZT>.

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