

# 2018 Lionfish Summit



**October 2-4, 2018**

**Cocoa Beach, Florida**

Hosted by the Florida Fish and Wildlife  
Conservation Commission

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## Media and Resources

- View photos in the [Lionfish Summit Flickr album](#).
- Live video footage broadcast by the Florida Channel:
  - [10/02/18 Florida Fish and Wildlife Conservation Commission Lionfish Summit](#)
  - [10/03/18 Florida Fish and Wildlife Conservation Commission Lionfish Summit Part 1](#)
  - [10/03/18 Florida Fish and Wildlife Conservation Commission Lionfish Summit Part 2](#)
- Video recordings of the oral presentations are available upon request by contacting [Lionfish@MyFWC.com](mailto:Lionfish@MyFWC.com).
- Visit [MyFWC.com/Lionfish](http://MyFWC.com/Lionfish) or [FWCReefRangers.com](http://FWCReefRangers.com) for agency information and lionfish resources.
- Additional questions? Contact the Division of Marine Fisheries Management at 850-487-0554.

## Introduction

### Background

The invasive Indo-Pacific lionfish (*Pterois volitans/miles* complex) were first reported offshore Broward County, Florida in 1985 and are now well established in the western Atlantic Ocean, Caribbean Sea, and Gulf of Mexico. The Florida Fish and Wildlife Conservation Commission (FWC) was one of the lead organizations to act by initiating procedures to evaluate the extent of the invasion, developing outreach and awareness messaging, removing potential regulatory barriers to removal, supporting control efforts, and implementing removal incentive programs. The FWC lionfish program was created within the Division of Marine Fisheries Management in 2014 and has grown significantly in four years. A complete summary of FWC's lionfish outreach and control programs can be found in Appendix F.

The FWC initiated the development of a statewide Lionfish Control Plan following an internal staff meeting in 2012 and the 2013 Lionfish Summit. The Lionfish Control Plan was completed in March 2018 and includes background information regarding the lionfish invasion, FWC's past and current involvement, and identified action items for the future of lionfish control in Florida. The document is available upon request by contacting [Lionfish@MyFWC.com](mailto:Lionfish@MyFWC.com).

### Mission Statement

The FWC will minimize the adverse impacts of lionfish in Florida through prevention, detection, and control by applying agency resources; providing leadership through guidance, planning, and coordination; and empowering stakeholders and partners.

### Desired Future Conditions

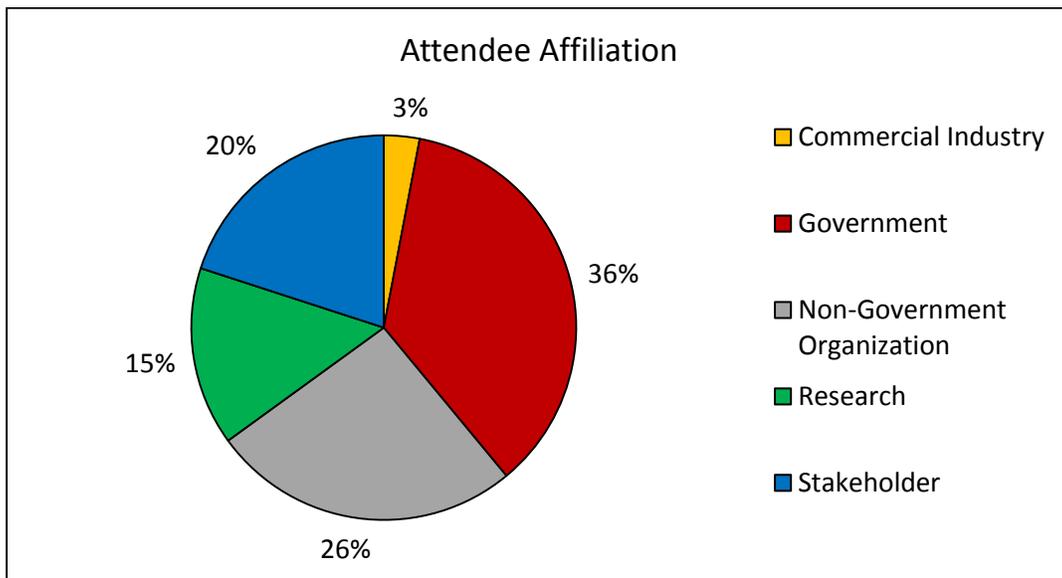
A Florida where;

1. The lionfish population is controlled so there are minimal negative impacts to species and habitats;
2. The public knows about the negative ecological and social impacts of lionfish and is knowledgeable about what to do when they encounter them;
3. The FWC is exercising leadership and co-manages lionfish collaboratively with sister agencies, non-government organizations, and stakeholders;
4. Stakeholders are engaged and empowered to implement appropriate management actions;
5. Stakeholder influence leads to political and financial support for a broad and adaptive suite of management actions; and,
6. Presence of lionfish causes minimal negative economic impacts.

### 2018 Lionfish Summit Introduction

The FWC hosted the second Lionfish Summit at the Hilton Oceanfront in Cocoa Beach, Florida on October 2-4, 2018. The goal of the 2018 Lionfish Summit was to assess the efficacy of current research, management, control, and outreach efforts; prioritize areas for future lionfish control; and improve collaboration among multiple agencies and geographic locations. The Summit was facilitated by Dr. James Perran Ross from Rocky Point Consulting. Dr. Ross' expertise in facilitation, strategic development, and conflict resolution on wildlife management topics, conservation planning and policy was vital in the execution of a successful event.

To accomplish the identified goals and achieve desired outcomes, the following were invited to provide comment: resource managers, researchers, non-governmental organizations, members of recreational and commercial sectors, and other stakeholders involved in lionfish policy, control, and/or education. The Summit was attended by 121 people and participants were primarily affiliated with one of the following categories: commercial industry, government, non-government organization, research, or unaffiliated stakeholder (Figure A). The Summit featured a total of 36 presentations, including 22 oral presentations and 14 poster presentations (Appendix B). Invited oral and poster presentations were categorized into one of three themes: Policy and Regulation, Control Efforts/Research and Monitoring, or Outreach and Education. The presentations served to inform participants of the current efforts throughout Florida and the invaded region.



**Figure A.** Affiliations of the 121 people that attended the 2018 Lionfish Summit.

Jim Estes, Deputy Director of the FWC Division of Marine Fisheries Management, opened the Summit with a brief background on the role of the FWC throughout the lionfish invasion and the importance of continued FWC partnerships with universities, organizations, and stakeholders for continued control of lionfish in the invaded range. Estes challenged Summit attendees to place a critical eye to current efforts for controlling the lionfish invasion, both within and outside of the FWC, and define the collective meaning of success as related to the desired future outcomes. While acknowledging the various opinions for achieving the desired future condition of lionfish in Florida, Estes emphasized immense progress achieved by the lionfish community in policy and regulation, outreach and education, control efforts, research and monitoring, and development of the commercial market.

William Patterson, Associate Professor at the University of Florida, delivered the keynote presentation for the Lionfish Summit. Patterson has been on the forefront of lionfish research within Florida and his research has primarily focused on population trends, ecological impacts, and the potential mitigation of lionfish throughout the northern Gulf of Mexico. Patterson has used a variety of

methods to address his research questions and the results have led to advancements in the knowledge of the lionfish invasion and direction of future research. Using scuba divers and remotely operated vehicles, Patterson has conducted long-term monitoring efforts on natural and artificial reef habitats to evaluate the effects of lionfish presence and abundance on native reef fish communities. Recent plateaus and even declines in lionfish populations suggest that factors such as density dependence, lionfish cannibalism, and the appearance of an ulcerative skin disease may be providing some measure of natural control. In his concluding remarks, Patterson highlighted the needs for future research in the efficiency of innovative removal methods, such as modified traps, in habitat beyond recreational scuba diving depths (>130') as well as continued monitoring of lionfish and native fish population dynamics throughout the northern Gulf of Mexico.

Following the welcome address and keynote speaker, the Summit proceeded with oral presentations and panel discussions for each of the three themes: Policy and Regulation, Control Efforts/Research and Monitoring, and Outreach and Education. Poster presentations were featured during the Lionfish Social held the first evening. The final day consisted of three independently-facilitated discussion groups for each theme of the Summit, with stakeholders assigned to a group based on their interests and expertise. Each group was presented with two questions to guide the discussion and tasked to develop and prioritize potential action items for each. The following report represents a comprehensive overview of the 2018 Lionfish Summit and its outcomes.

## **Theme I: Policy and Regulations**

The policy and regulations theme reviewed processes and management actions implemented by state and federal agencies to address the lionfish invasion and mitigate their impacts on native species and habitats. State and federal agencies have sought to remove potential barriers for lionfish harvest by adopting policies that encourage involvement and make it easier for stakeholders to understand and contribute to removal efforts.

At the state level, the FWC's goal to encourage removal efforts was addressed by removing the requirement to possess a recreational saltwater fishing license when harvesting lionfish with approved or lionfish-specific gear, removing the recreational default bag limit, and allowing scuba divers using a rebreather apparatus to harvest lionfish. The FWC has also implemented various incentive programs that include prizes and resource-based incentives to encourage and increase lionfish removals. To supplement these changes and prevent additional release of lionfish, state regulations have been put into effect to prohibit the importation, breeding, and possession of lionfish eggs or larvae. While the harvest of lionfish and many other species remain restricted in ecologically sensitive or protected areas and areas where harvest presents a public safety concern (i.e. near fishing piers and jetties), the FWC has created a permitting system to allow for harvest of invasive lionfish in these areas within certain limitations. The FWC encourages stakeholders to provide feedback on current regulations and ways in which the state can be more effective at managing efforts and communicating information regarding invasive species to the public.

At the federal level, the National Oceanographic and Atmospheric Administration (NOAA), in partnership with the regional fishery management councils, oversees the management of marine resources from state waters to 200 nautical miles offshore. NOAA Fisheries encourages lionfish removal, but in order to protect native species and critical habitat areas, innovative harvest methods and gear testing conducted in federal waters require a federal permit as well as review and approval by the applicable Fishery Management Council. Permits include either an Exempted Fishing Permit or a Letter of Acknowledgement, which are issued to organizations and researchers to test innovative gear for lionfish harvest, such as modified lobster traps. The majority of deep-water habitat existing beyond recreational diving depths (>130') are under federal waters jurisdiction, therefore the partnership between state and federal agencies is crucial for the development and successful implementation of innovative harvest methods across depths and management boundaries.

The 2018 Summit provided an opportunity for agencies to share updates on regulatory and policy changes implemented since the 2013 Summit. The facilitated breakout sessions afforded stakeholders an opportunity to voice their opinions related to current regulations and potential regulatory changes in the future.

### **A. Oral Presentations**

Presentations related to the Policy and Regulation theme were given by Kali Spurgin (FWC), Dr. Stephen Gittings of the National Oceanic and Atmospheric Administration (NOAA), and Kelli O'Donnell (NOAA).

Spurgin summarized the previous five years of the FWC's lionfish program, including policies and management changes regarding invasive lionfish. The removal of regulatory barriers (as described

above) as well as the implementation of various incentive programs for lionfish removals have successfully encouraged diver participation in lionfish removal efforts. Initiatives to increase lionfish harvest and stakeholder engagement include supporting lionfish removal tournaments through the Tournament Assistance Program and other FWC-administered programs, such as the Lionfish Challenge, that distribute prizes such as harvesting gear and a commemorative coin to harvest an extra lobster during the two-day sport season. The FWC supports the research and development of innovative harvest gear, such as lionfish-specific traps and remotely-operated vehicles, to harvest lionfish beyond recreational diving depths. The FWC also provides financial assistance through the Lionfish Harvest Charter Program in an effort to increase the number of divers harvesting lionfish and the number of lionfish removed. Lionfish outreach programs provide accurate and consistent educational messaging to a wide audience through classroom dissection activities, a traveling “Be the Predator” booth at festivals and events, and “Become the Predator” diver workshops to teach harvest and safe-handling techniques.

Dr. Gittings provided insight into the process of developing a lionfish-specific trap and acquiring permits for testing this equipment in state and federal waters. The FWC is the state agency responsible for reviewing and issuing permits for gear testing in state waters, and NOAA is responsible for reviewing and issuing permits for gear testing in federal waters. The trap design developed by Dr. Gittings has been published for distribution and widely tested throughout the invaded range, and Dr. Gittings has obtained permits for use in state and federal waters, including protected areas like the Florida Keys National Marine Sanctuary (FKNMS). The primary issues that NOAA identified as barriers to approval of a lionfish-specific trap are the potential implications for ghost fishing (lost or abandoned traps continuing to fish), bycatch, and disturbance to protected species and critical habitats. Dr. Gittings discussed the evolving design of his trap to minimize these issues, such as using a hinge to eliminate the possibility of ghost fishing if the trap is lost and using different mesh and attachment clips to reduce snagging for easier storage on commercial vessels. The modification of a fish aggregating device within the trap reflects attempts to specifically target lionfish and reduce bycatch; and the use of different ropes, clips, and trap shapes were explored to identify a durable material least likely to cause entanglements. Gittings’ presentation illustrated the lessons learned as well as various policies and permitting requirements to test innovative gear in deep-water habitats.

O’Donnell provided an informative, distinct picture of the role of NOAA Fisheries in lionfish removal efforts within federal waters, a subject that has remained unclear to much of the lionfish community and public alike. She elaborated on the various challenges and potential repercussions that NOAA must consider for technical, regulatory, and policy changes. NOAA Fisheries, in collaboration with the regional fishery management councils, manages fisheries in federal waters under the Magnuson-Stevens Fishery Conservation and Management Act. The primary objective of the Magnuson-Stevens Act is to prevent overfishing and maximize the yield produced by fisheries over the long term. This concept is relevant when applied to native fisheries but contradicts the objective of removing invasive species such as lionfish. While lionfish harvest in federal waters is unregulated, the allowable gear for harvesting any species is restricted to certain types. NOAA Fisheries strongly supports efforts to design and test gear that could be used to further develop the commercial lionfish market and issues special gear and exempted fishing permits for lionfish harvest in federal waters. Individuals intending to utilize restricted gear types, such as modified or lionfish-specific traps, must apply for either an Exempted Fishing Permit or Letter of Acknowledgement. The type of permit issued is dependent on the applicant’s affiliation, such as a researcher, private organization, or commercial harvester. Applications must include detailed

information on the gear to be used, locations of testing, the target species, potential impact to all regulated species, and vessel information. In response to the increase in number of applications for lionfish gear testing permits, NOAA recently completed several programmatic environmental review documents to evaluate the native species and habitats that may be influenced by incorporating lionfish removal gear in federal waters. Based on the results of these environmental reviews, NOAA has issued one Exempted Fishing Permit and seven Letters of Acknowledgement for testing various trap designs as well as approved the use of a remotely operated vehicle (ROV) for removal in the Gulf of Mexico to date. O'Donnell's presentation provided important insight on federal regulations and highlighted the collaboration between NOAA Fisheries and the regional fishery management councils.

## **B. Panel Discussion**

Panelists for the Policy and Regulations section included Heather Blough (NOAA), Daniel Ellinor (FWC), Dr. Stephen Gittings (NOAA), and Kelli O'Donnell (NOAA). After introductions by each panelist, the discussion began with additional focus on federal policies and protocol related to lionfish removal efforts. Blough emphasized the South Atlantic Fishery Management Council's support of current lionfish control efforts and continued interest in development and monitoring of effective removal methods that minimize negative effects on native species and habitats. The panel noted that restrictions on trap use in federal waters have taken years to develop and further modifications will take time. The continued research on lionfish traps will be taken into consideration when implementing changes to federal gear policies. It was also noted that data reflecting the effects of traps on native species and habitats must be obtained in local waters to verify that changes to management are necessary. Furthermore, gear testing projects for federal exemption permits must be appropriately unique to avoid duplicate research permits. Efforts to establish an allowable bycatch limit for traps are ongoing and will reflect findings from trap results for currently-issued permits.

In ecologically sensitive locations such as the FKNMS, both state and federal permits are required to harvest lionfish. Divers must receive a harvesting permit from the Sanctuary and a gear exemption permit from the FWC to harvest from protected reefs. The permits that FWC issues for removal of nonnative species within areas otherwise prohibited to spearing are only issued for organized events (such as lionfish tournaments) or to groups (such as dive clubs). Stakeholders are often unaware of this process. The FWC received feedback from constituents regarding the need to increase awareness on the state permitting process for lionfish removal in protected areas. Panelists noted that spearing prohibitions will not be removed as they are necessary for public safety and to minimize negative impacts on native natural resources.

Lastly, the panel addressed a question concerning the aquarium trade's continued sale of lionfish. The FWC prohibits the import and propagation of lionfish (*Pterois miles* and *P. volitans*) in Florida, but aquarium specimens can be collected from Florida waters and sold legally through the aquarium trade. While these removals contribute to control efforts, they still pose a risk for subsequent releases of lionfish. Current messaging emphasizes the adverse impacts that releases can have on the environment; however, increased outreach and education on proper nonnative pet ownership and increased regulation of additional species of lionfish in the aquarium trade may be necessary.

### C. Discussion Group

The Policy and Regulations discussion group consisted of 6 participants and included researchers, resource managers, and stakeholders. Each discussion group had a facilitator and notetaker.

The group was presented with two topics for discussion:

1. *What current state and federal policies and regulations are effectively encouraging or discouraging lionfish removal?*
2. *Identify modifications to state and/or federal policies and regulations that will effectively advance lionfish removal and control.*

The information below consists of all recorded recommendations and action items identified by stakeholders for current and future lionfish policy and regulation initiatives:

**Session 1:** What current state and federal policies and regulations are effectively encouraging or discouraging lionfish removal?

#### **Effective efforts:**

- State incentive programs (i.e. Lionfish Challenge).
- Removal of bag limit, recreational license requirement, season, and size restriction.
- Use of federal permits for removals in otherwise prohibited areas.
- Tournament support and media promotion of these events.
- Staff assistance in navigating permit process without the need for legal counsel.
- Adaptive management strategy of the state's rules and regulations for lionfish.

#### **Ineffective efforts and identified areas of improvement:**

- Increase outreach on the permitting process for removals at the state and federal level.
- Consensus on the definitions of federal regulations.
- Improve communication and flexibility between state and federal agencies on managing lionfish harvest and research permits.
- Simplify the rules for harvesting in sanctuaries.
- Expedite the federal permitting process.

**Session 2:** Identify modifications to state and/or federal policies and regulations that will effectively advance lionfish removal and control.

Six people voted. Total number of stakeholder votes in parentheses and ranked from highest to lowest priority based on results.

1. FWC staff provide updates about lionfish at the Diving Equipment and Marketing Association's annual conference. (6)
2. Communicate with and involve the hotel and restaurant association in lionfish events. (6)
3. Target workshops for fishermen to learn about commercially harvesting lionfish. (6)
4. Increase stakeholder involvement in regional council meetings to inform councils on lionfish issues. (6)
5. Create a joint lionfish task force with state and federal agency staff to address expediting rule and permitting issues. (5)

6. Identify special circumstances that qualify for emergency response exemptions. (5)
7. Open communication between legal counsels to create consensus. (5)
8. Mail flyers to commercial and recreational fishermen regarding lionfish licensing and permitting options. (5)
9. Receive direction from agency leadership to address lionfish issues as a priority with more state agencies inviting involvement of federal agencies. (5)
10. Invite regional fisheries management councils to attend lionfish summits and workshops. (5)
11. Creation of a regular allowance or permit for divers to remove lionfish from federal and state restricted areas. (5)
12. Increase outreach to lionfish harvesters concerning commercial fishing rules such as trip ticket submissions and product handling safety. (5)
13. Exclude lionfish from normal permitting process for nonnative species emergency response. (4)
14. Target outreach to dive shops, Saltwater Products License applicants, new and renewing license holders. (3)
15. Provide financial incentives for technology advances. (1)
16. Provide workshops to clarify legal definitions and consolidation of state and federal regulations. (1)
17. Implement a state rule to require a diver to report and/or remove a nonnative species, if observed. (0)

## **Theme II: Control Efforts/Research and Monitoring**

The control efforts/research and monitoring theme encompassed a very broad range of topics, including various programs and initiatives to control lionfish populations, current research advancements, the efficiency of monitoring and removal efforts, and identifying priority areas to direct future work. Throughout the last decade, an increasing amount of research has focused on the impacts of the invasive lionfish on native species and habitats and the efficiency of removal and control efforts. Lionfish will likely never be eradicated from the western Atlantic Ocean, Caribbean Sea and Gulf of Mexico. Highly-focused research, monitoring, and control efforts are a top priority to implement effective lionfish control strategies and minimize adverse impacts. Due to limited resources such as funding, skilled lionfish harvesters, and the ability of lionfish to inhabit depths beyond the range of the current most-effective removal strategies (i.e. divers using spearfishing equipment), there is an increasing need to identify critical habitats for priority removal efforts and to develop more-efficient removal methods. Funding from private organizations and state and federal governments have allowed for an increase in the quality and quantity of research projects on invasive lionfish throughout their invaded range, however gaps remain in the research that can be applied to improve management strategies. The 2018 Summit provided a platform for individuals to share this work, which included 10 oral presentations addressing various aspects of the control efforts/research and monitoring theme, a panel discussion with six experts, and a discussion group with 30 stakeholder participants.

### **A. Oral Presentations**

Representatives from universities, private organizations and state and federal agencies presented their work related to the control efforts/research and monitoring theme. Research presentations largely focused on three areas: 1) trends in lionfish populations on a temporal and spatial scale as well as by habitat type; 2) the efficiency of lionfish removals and the effort required to mitigate the impacts of lionfish; and 3) the biology and ecology of lionfish throughout their invaded range.

The session began with a presentation by David Chagaris, University of Florida (UF), in which he presented his ecosystem-based approach to evaluate the ecological consequences of the lionfish invasion on native species and habitats. This approach provides a better understanding of the impacts of lionfish over large spatial scales by improving the design of management strategies and removal efforts. Ecosystem models are useful tools for controlling invasive species because it allows resource managers to predict the effects of potential management decisions. Comprehensive field survey data from the Gulf of Mexico was incorporated into the ecosystem models and the results successfully replicated observed trends in lionfish and associated population declines in their prey. Future models will incorporate the depth-limitations for divers harvesting lionfish in water up to 130 feet as well as focus on the ideal exploitation rates, frequency of removals, and spatial distribution for targeted lionfish removals. The development of innovative tools such as ecosystem models may improve the efficiency of removal efforts across spatial scales as well as provide resource managers with a better understanding of the effects of invasive lionfish when proposing various management decisions.

Christopher Stallings, University of South Florida (USF), presented his research using a “before-after-control-impact” experimental approach to investigate the effort required to “fish down an invasive species” and therefore reduce their impacts, in protected areas that are absent of heavy fishing pressure. Results indicated that monthly removals had a significant effect on reducing lionfish density

(compared to control sites), but there was no evidence to support that lionfish removals (regardless of frequency) influenced lionfish biomass or native prey size, abundance, and diversity. The study was conducted within Biscayne National Park on a continuous, natural reef ledge, which suggests that the results may be specific to habitat type. Therefore, future research should include this as an experimental variable.

Similar research questions were investigated by Holden Harris, UF. Harris' research evaluated the efficiency of lionfish removals in the northern Gulf of Mexico by either scuba divers using spearfishing equipment on natural and artificial reefs or by non-containment, curtain traps deployed near artificial reef habitat. Results indicated that divers were more efficient at removing lionfish from artificial reefs (87% removed) compared to natural reefs (59% removed). Investigation on the removal efficiency of traps in deep-water habitat is being conducted in relation to trap soak and retrieval time, trap density, and proximity to source reefs. Lionfish removals from deep-water habitats (beyond recreational diving depths of 130 feet) remains a priority focus because these areas act as a refuge protected from diver removals and may subsequently act as a source population for shallow-water reefs. Stallings and Harris highlight the need to evaluate removal efficiency across different habitat types and regions within the invaded range to provide better management strategies, improve control efforts, and mitigate the impacts of invasive lionfish.

Presentations by Amanda Tyler-Jedlund (FWC) and Kristen Dahl from UF focused on the habitat dynamics of lionfish in the Gulf of Mexico. Tyler-Jedlund used side-scan sonar mapping and underwater camera imagery data from 2014-2017 to identify specific habitat types with higher densities of lionfish. Results indicated that lionfish aggregate on natural and artificial reef habitats with relief throughout the eastern and northern Gulf of Mexico, but in both regions, lionfish were found in higher density on artificial habitats in deeper waters (38-180 meters). This research provides a better understanding of lionfish populations across large spatial scales and beyond depths accessible by recreational scuba diving and harvest pressure. The results could improve management strategies as well as help direct control efforts for lionfish removal from specific habitat types, depths and regions of the Gulf of Mexico.

Dahl investigated lionfish density, condition and growth on natural versus artificial reef habitats across five years within the northern Gulf of Mexico. Results revealed that lionfish densities were two orders of magnitude higher and the mean size and growth rates were lower on artificial reefs compared with natural reefs, suggesting that density influenced body condition and growth. Analysis of lionfish stomach contents from areas of high adult lionfish densities revealed that 26% of lionfish prey items are cannibalized lionfish, suggesting that cannibalism has the potential to influence population dynamics in areas of high lionfish densities. These projects by Dahl and Tyler-Jedlund reinforce the importance of 1) considering habitat dynamics for shallow and deep-water removal efforts to maximize efficiency and reduce time and resource expenditures, and 2) monitoring lionfish populations and native habitat dynamics over large temporal and spatial scales in order to identify changes or trends in the density and distribution of invasive and native species.

Alli Candelmo from Reef Environmental Education Foundation (REEF) discussed the results from 10 years of REEF tournaments, including the harvest trends over space and time and limitations to the data. Lionfish tournaments are an effective removal strategy that have been shown to reduce lionfish populations on a localized scale, increase awareness, and increase the number of divers proficient at harvesting lionfish. Lionfish harvest is often sold to the commercial market and chefs prepare lionfish for

public consumption, which supports the commercial industry and promotes awareness and consumption. Tournaments have been a popular removal method over the past decade and remained a prominent discussion topic during the 2018 Lionfish Summit. Candelmo's results suggest that tournaments can in fact reduce local populations of lionfish, but tournament data can be inconsistent over time due to varying diver and harvesting experience, weather, tournament length (catch per unit effort), and other factors that influence tournament success and public participation. As the invasion progresses and lionfish populations adapt and respond to fishing pressure, tournaments for divers harvesting lionfish in shallow waters will also have to be complemented by innovative harvest methods, such as traps and ROVs in deep-water habitats.

Another benefit of tournaments is the large quantity of lionfish that are harvested from a specific area and within a short period of time. This "snapshot" sample allows for the harvest to be used for research projects that aim to gain a better understanding of invasive lionfish biology and their effects on native species and habitats. Eric Johnson, from the University of North Florida (UNF), partnered with lionfish harvesters, dive charter captains, non-profit organizations and local agencies to obtain lionfish samples and investigate multiple biological and ecological parameters of lionfish populations within northeast Florida. Results indicated that lionfish exhibit seasonal variation in growth rates, consume primarily finfish, are on average less than two years of age, and contain mercury levels far below other commonly-consumed marine finfish. This project is an example of the success of collaborations between researchers and stakeholders that can provide a better understanding of the biological and ecological effects of invasive lionfish. Projects such as Johnson's could inform management plans across spatial and temporal scales to best mitigate the negative impacts of lionfish.

The majority of reef habitat within Florida is open for harvest of many species and easily accessible for spearfishing activity by scuba divers. In contrast, the Flower Garden Banks National Marine Sanctuary is a protected area located approximately 100 miles off the coast of Texas. Research presented by Michelle Johnston, from the NOAA Office of National Marine Sanctuaries, revealed that lionfish have not had a negative effect on native reef fish density or community composition since invading these reefs in 2011. A potential reason could be the absence of fishing pressure on all levels of the food web, which allow for higher species diversity within the Flower Garden Banks compared to areas where heavy fishing pressure may have reduced densities of top predators that may otherwise compete with lionfish for resources. Future results from long-term monitoring efforts may reveal other potential impacts from invasive lionfish. Therefore, maintaining this research is vital to the detection and documentation of invasive species within protected areas.

Kate Galloway, from Florida Atlantic University, presented research on the mechanical properties and puncture performance of each of the three fins containing venomous spines (dorsal, pelvic and anal). Although lionfish were reported in Florida waters over 30 years ago, research and investigation on their venomous spines is still largely underdeveloped and this defense mechanism remains a common source of misconception with the media and stakeholders. Galloway's project aimed to investigate the effectiveness of these lionfish features as a defense mechanism against predation. Results showed that the pelvic and anal spines had greater stiffness, resilience, and toughness when used in a puncture test at various locations within a black grouper's mouth. Additionally, results suggest that the pelvic and anal spines absorb more energy and may be more effective as a defense mechanism compared to the dorsal spines, which may primarily serve as an intimidation strategy.

The session concluded with a presentation by Mohammad Shamim Ahasan, from UF, on the investigation of an emergent ulcerative disease in lionfish throughout the invaded range. The ulcerative skin disease was first reported in 2017 in the Gulf of Mexico and subsequent reports have been submitted from the Caribbean, Florida Keys, and northeast Florida in the western Atlantic Ocean. Results indicated an absence of parasites from ulcers found on the fin, gill and skin; inconclusive results for a bacterial pathogen from the ulcer, kidney, liver, and brain; and some lionfish have demonstrated attempted healing of the ulcerative tissues. Ahasan and colleagues are currently analyzing DNA samples as well as continuing to collect and process viable samples to gain a better understanding of the possible cause(s) of the disease and the potential implications for lionfish condition, growth and population dynamics. The FWC, UF, Fish and Wildlife Research Institute (FWRI), county agencies, non-profit organizations, and stakeholders have collaborated to compile and standardize reports, collect samples, and further investigate the cause(s) and consequences of this ulcerative disease.

## **B. Panel Discussion**

After introductions by each panelist, the Control Efforts/Research and Monitoring panel discussion addressed a variety of topics and answered questions from the audience. Panel members included the following: Lad Akins (Blue Earth Conservation), David Chagaris (UF), Eric Johnson (UNF), William Patterson (UF), Christopher Stallings (USF), and Hanna Tillotson (FWC).

The discussion began with a continuation of the emerging ulcerative disease that has been reported in lionfish and stakeholders suggested the use of introducing host-specific pathogens to facilitate the reduction of lionfish. Panelists agreed that this method is nearly impossible to effectively implement and there are numerous unknown ecological effects on native species and habitats when resource managers introduce external pathogens or predators from an invasive species' native range. Alternatively, regions with high densities of lionfish may benefit from the absence of removal efforts, such as fishing pressure. Absence of removal efforts may increase cannibalism and disease prevalence and intensity, which may then serve as a potential natural control. Examples of this include the Flower Garden Banks National Marine Sanctuary and other areas that are protected from regular harvesting pressure and therefore retain higher native species diversity and lower densities of invasive lionfish.

A prominent question and topic for discussion throughout the Summit was the current population densities of lionfish in shallow (<130') and deep-water habitat. The ability to evaluate the success of removal efforts by divers in shallow-water habitats depends on having survey data over large spatial and temporal scales. However, the current available data is only robust over smaller regions and time periods. The quantity of lionfish removed through lionfish tournaments, commercial harvest, and various control and incentive programs provide an estimate of lionfish populations by county or region. However, this data is largely a function of harvesting pressure and not lionfish population density. Trends in lionfish removals over time can be considered for potential management implications, but the limitations and lack of standardization of the data must be acknowledged.

Lastly, the panel discussed habitat availability and the role that various habitat types can have on lionfish populations and how this could help guide future management strategies. While there are many factors contributing to the presence and density of lionfish within a given area, habitat type is one of the most important factors for lionfish recruitment, settlement, body condition, and growth. Florida has invested a significant amount of resources to maintain one of the most active artificial reef programs in the country. These man-made reef modules and wrecks are important habitats for native fish and

invertebrate species and they support sustainable marine fisheries. However artificial reefs also support high densities of lionfish populations. Future construction and management of artificial reefs should consider this reality and explore new opportunities for creating reefs that are less appealing to invasive lionfish.

Overall, the panel discussion provided a platform for prominent experts within the Control Efforts/Research and Monitoring field to share their knowledge regarding the status of the lionfish invasion and provide guidance for future priority areas.

### **C. Discussion Group**

The Control Efforts/Research and Monitoring discussion group consisted of 30 participants and included researchers, commercial harvesters, non-profit and private organizations, local and state resource managers, dive shop owners, concerned stakeholders and industry professionals. Each discussion group had a facilitator and notetaker.

The group was presented with two topics for discussion:

1. *Identify current control efforts that are effectively encouraging or discouraging lionfish removal; and identify current research initiatives that are effectively advancing lionfish control efforts.*
2. *Identify and develop control programs and/or research projects that will effectively advance lionfish removal and control.*

Participants listed action items pertaining to the two topics (above) for the control efforts theme as well as for the research and monitoring theme and then categorized the action item as one of the following:

- [W] = action item is **working**
- [WA] = action item is **working with adjustments**
- [F] = action item for **future** work

The information below consists of all recorded recommendations and action items identified by stakeholders for current and future lionfish control efforts and research and monitoring initiatives:

#### **Control Efforts**

##### **Action item is working**

1. Control efforts (and general lionfish removal culture) in the Florida Keys.

##### **Action item is working with adjustments**

1. Control efforts focused regionally and by water depth.
2. Develop comprehensive report of statewide control efforts, to include the following:
  - a. Database of participants.
  - b. Standardize control efforts and data collection.
  - c. Expand use of existing Gulf and Caribbean Fisheries Institute (GCFI) Portal for public reporting.
3. FWC Reef Rangers “Adopt-A-Reef” Program
  - a. Improve access of reefs and maps for harvesters to direct focal removal efforts.

- b. Validate artificial reef locations to improve accuracy.
  - c. Identify preferred habitat for lionfish populations (and include with reef information) to direct focal removal efforts.
- 4. Lionfish tournaments
  - a. Optimize regionally.
  - b. Conduct commercial tournaments or have an alumni division.
  - c. Increase registration fees.
  - d. Need for consistent recreational harvesters and participation.
  - e. Encourage involvement with various incentive programs during tournament.
  - f. Ensure legal commercial harvest and sale of lionfish by participants.
  - g. Increase prize or award for harvesting small lionfish.
  - h. Provide training for recreational harvesters becoming involved in commercial market.
- 5. Commercial market
  - a. Increase price per pound of lionfish for wholesale market (provide a state subsidy).
  - b. Encourage the removal of all sizes of lionfish by creating a state subsidy.
  - c. Provide commercial market education in various outreach initiatives (for example: Saltwater Angler magazine and publications).
- 6. FWC Lionfish Harvest Charter Program
  - a. Increase program advertisement.
  - b. Increase vendor qualifications.
  - c. Return to initial goal of encouraging new divers to become lionfish harvesters.

**Action item for future work**

- 1. Commercial market
  - a. Lionfish harvester training – use a mentor or team approach.
  - b. Develop new markets.
  - c. Promote use of small lionfish.
- 2. Identify incentives for different demographics and target those stakeholder groups efficiently.

**Research and Monitoring**

**Action item is working**

- 1. Ongoing research on the effects of lionfish on native species and habitats throughout invaded range.

**Action item is working with adjustments**

- 1. Research and development of innovative harvest gear testing and lionfish traps.
- 2. Efficacy of human control efforts.
- 3. Accuracy of available data of population estimates on artificial reef habitats.
- 4. Maintain accurate information on state and federal permitting and gear-testing process on websites and in media.

### **Action item for future work**

1. Investigate regional differences in lionfish abundance. Is this due to natural variations or control efforts?
2. Investigate potential control mechanisms (human and biological); invest in cause and effect research.
3. Projected lionfish populations and effects in future models.
4. Improve accuracy and reporting of commercial lionfish sales and trip ticket reporting system.
5. Lionfish-specific fish-aggregation devices (FAD).
6. Identify research gaps and support research to guide control efforts:
  - a. Reproductive behavior.
  - b. Source and sink populations.
  - c. Life history strategies; spawning behavior (focal habitat and movement strategies).
  - d. Ecosystem and population model validation.
  - e. Net ecological effects of harvest and potential increased productivity.
  - f. Data collection at tournaments (standardize across organizations and regions).
  - g. Investigate economic risk assessments and develop impact statements.

## **Theme III: Outreach and Education**

The outreach and education theme discussed the various methods that are used to ensure accurate, consistent, and updated messaging within schools, the commercial seafood industry, and recreational diving community. Outreach and educational tools are key components to obtain and maintain control of an invasive species because it is the mechanism by which the public is inspired to act. The Summit featured seven presentations by representatives from research, private, and non-profit organizations, the seafood industry, and government agencies. The presentations showcased current efforts, successes, and future strategies for outreach and education initiatives throughout the invaded range.

### **A. Oral Presentations**

One of the top priorities of outreach and education initiatives across stakeholder groups is to maximize the reach of consistent and accurate messaging about the lionfish invasion and their impacts on native ecosystems. Effective control of the lionfish invasion narrative is dependent on the cooperative efforts of stakeholder groups. This collaboration requires the public understand potential threats that can result from invasive species, and their role in preventing or minimizing these impacts. Presentations conducted by LeRoy Creswell of Florida Sea Grant, and Jim Hart and Stacy Frank of Lionfish University emphasized the importance of not only creating a diverse array of outreach materials, but also the vitality of efficient communication among parallel groups and initiatives. State agencies, non-governmental organizations (NGOs) and the private industry rely on communication “bridges” to share progress, lessons learned, and prevent duplication of effort. Organizations such as Sea Grant and Lionfish University have a unique ability to reach across state and international lines, providing important educational tools and sources of information that management agencies may otherwise be unable to access.

Brady Hale of Texas Lionfish Control Unit demonstrated the application of marketing strategies to elicit a desired change in targeted audience behavior. A recurring discussion topic within this theme of the Summit centered around recruiting and retaining a larger target audience to participate in ongoing control efforts. Anecdotal evidence presented during the Summit indicated that general awareness campaigns have been extremely successful over the last five years. Hale’s presentation focused on building upon this foundation to begin a more direct focus on driving an audience to action. For example, Hale’s organization provides a direct call to action for the lionfish invasion by hosting lionfish excursions to increase the number of divers that can confidently and proficiently harvest lionfish. To bolster current efforts, Hale poses, lionfish experts have a certain degree of responsibility to provide stakeholders with an opportunity for active participation. This change in behavior, or call to action, can be achieved by eliminating potential barriers to change, providing specific direction for action, and providing information that helps promote physical and emotional connections to a concept such as lionfish.

Jeff Eble of the University of West Florida (UWF) showcased another example of action-based involvement: a travelling genetics lab for analyzing lionfish gut contents in schools. Eble has created a curriculum that allows middle and high school students to use the scientific method as it applies to a current local issue. Involving students in real-world problems by integrating research and education has proven to be successful and will continue to stimulate interest in science, technology, engineering and math (STEM) fields. Jeff’s work and that of other government, private, and non-profit organizations

contributing to the development and investment in the next generation highlight the need for directed outreach to children. While there are a wide variety of existing educational materials and initiatives to promote awareness for children, it was acknowledged by many at the Summit that a more concerted effort to expand these programs is necessary for continued success.

Lionfish tournaments and festivals are generally recognized as successful venues to recruit and retain stakeholder interest. Featuring vendors, free lionfish tastings, and a lionfish tournament, these large events typically draw a diversity of targeted audiences. The multi-faceted approach to general awareness, garnering involvement, and encouragement of lionfish as a food source make these events efficient channels for messaging. Kendra Cope of Indian River County (IRC) discussed the challenges organizers face when planning large outreach events and pointed out that occasionally these events can exacerbate existing gaps. Discussions at the Summit provided significant evidence that the palatability of lionfish has received significant attention throughout Florida and the nation and therefore the lionfish commercial market is now limited by supply, rather than demand. Many local and national restaurants and store chains are now unable to supply lionfish on a consistent basis to meet the increasing demand. Kendra demonstrated this through a survey that was distributed to local commercial harvesters, restaurant owners and seafood wholesale dealers to identify their knowledge of the industry as well as potential barriers to the success of the commercial lionfish market. The method presents an example of an effective tool that can be used to evaluate the status of stakeholder involvement within the commercial industry as well as initiatives to improve communication between all facets of the lionfish supply chain, from the reef to restaurant.

Furthermore, a recurring point of discussion throughout the Summit was the status and future of the lionfish commercial market. Florida has seen an extensive increase in lionfish landings over the past five years, though recent data shows the rate of increase could be slowing. The FWC understands the fragile balance between encouraging the commercial harvest of lionfish as a means of control and preventing it from becoming a managed “fishery.” David Ventura, seafood coordinator for Whole Foods Florida, gave insight into a wholesale and retail perspective on the lionfish market. Businesses like Whole Foods Market act as an overlay between the business and outreach components of the larger lionfish issue. Customers are provided with continuing education and opportunity to act through the point of sale.

Lastly, Gretchen Goodbody-Gringley of the Bermuda Institute of Ocean Sciences touched on the subtleties of the lionfish market and public perceptions in the exhibition of her work in Bermuda. In addition to studying the science behind the lionfish invasion of the island, a very small and selective group of divers are distributing their catch to encourage a local fishery. However, regulatory barriers and poor public perception continue to persist among locals and fishermen alike. This example draws attention to the fact that the creation, expansion and support of a lionfish commercial market is a complex issue that spans multiple international governments and cultures.

## **B. Panel Discussion**

Upon conclusion of oral presentations and introductions by each panelist, experts serving on the Outreach and Education panel addressed a variety of topics. Panel members included the following: Kendra Cope (IRC), Gretchen Goodbody-Gringley (Bermuda Institute of Ocean Sciences), Brady Hale (TCLU), Rick O’Connor (Florida Sea Grant), Alan Peirce (FWC), and David Ventura (Whole Foods Florida).

Panelists addressed additional questions that arose during the presentations, including the viability and barriers surrounding the lionfish commercial market, the importance of standardized messaging, and increasing the efficiency of how outreach materials are disseminated. Throughout the discussion it was apparent that identifying target audiences and continuing to evolve our communication strategies is consistently a top priority among outreach and education experts. Panelists acknowledged that supplemental calls for action focusing on other ecological elements would add value to current lionfish outreach efforts. For example, creating additional campaigns such as the conservation of top marine predators (i.e. sharks, groupers) would allow resource managers and scientists to incorporate other important conservation messages into the current momentum of lionfish awareness efforts.

Another predominant topic of the panel discussion involved addressing the various gaps in the establishment of the consistent supply of lionfish sold to the commercial market. Some groups advocated for driving up the price of lionfish as a high-end food product while others argued for additional efforts to strengthen the supply chain. Many stakeholders attested to the challenges that commercial lionfish harvesters encounter in finding consistent sources of lionfish to become established in the market. Attendees also highlighted the lack of communication between wholesale dealers, retail buyers and lionfish harvesters.

The Outreach and Education panel discussion highlighted the immense success of current efforts aimed at addressing the lionfish invasion while also reiterating some elements that remain to be accomplished. Continued improvements to lionfish outreach and education initiatives are contingent upon effective communication among resource managers, researchers, and public stakeholders. Moving forward, efforts should focus on creating opportunities for public action in parallel with general awareness campaigns.

### **C. Discussion Group**

The Outreach and Education discussion group consisted of 14 participants and included local and state resource managers, non-profit organizations, dive shop owners, marine science researchers, educators, a screenwriter, and concerned stakeholders. Each discussion group had a facilitator and notetaker.

The group was presented with two topics for discussion:

1. *Identify current outreach and educational initiatives that effectively advance lionfish awareness and stakeholder engagement.*
2. *Identify and develop (current/future) outreach and educational programs that will effectively advance lionfish awareness and stakeholder engagement.*

The information below consists of all recorded recommendations and results of stakeholder prioritization for current and future lionfish outreach and education initiatives:

**Session 1:** Identify *current* outreach and educational initiatives that effectively advance lionfish awareness and stakeholder engagement.

- Continue to grow and improve on Florida's Lionfish Removal and Awareness Day by expanding efforts to large events across Florida and other Atlantic and Gulf states.
- Involve K-12, undergraduate and graduate students in lionfish tournaments.

- Expand participation in the Harvest Charter Reimbursement Program through outreach and regionalization.
- The Lionfish Challenge has been a successful incentive program, but may be nearing its maximum, effective potential.
- Increase and improve the communication process including increased advertising efforts, expanding social media, coupling research and outreach initiatives, and using local businesses/organizations across the state.
- Increased lionfish tournament duration and/or geographic locations to account for marine conditions and weather, which may limit diving activities.
- Expand participation in Lionfish Educational Exhibit Program through outreach and addition of incentives.
- Expand and implement “Lionfish: Classroom Invasion!” program on a larger scale.
- Use technology to amplify reach of current programs and maximize their effects.
- Continue to provide Dive in Day (DEMA) outreach and networking opportunities for local organizations.
- Facilitate pairing of “Become the Predator” workshops with themed dive clubs.
- Identify a clear message and specific calls to action for each FWC Lionfish program.
- Incorporate more interactive activities at “Be the Predator!” booth: such as a live lionfish or videos of live lionfish.
- Use “Be the Predator” as a brand and incorporate into all outreach efforts and programs.

**Session 2:** Identify and develop *future* outreach and educational programs that will effectively advance lionfish awareness and stakeholder engagement (13 total people voted, each participant was able to cast 2 votes). Total number of stakeholder votes in parentheses and ranked from highest to lowest priority based on results.

1. Host a National Lionfish Summit that includes the Caribbean. (8)
2. Create lionfish tech-based children’s games such as mobile apps or video games. (6)
3. Attend the Florida Science Teachers Association and Florida Marine Science Educator’s Association conferences and involve groups in outreach initiatives. (5)
4. Improve upon existing and create additional lionfish Public Service Announcements. (3)
5. Create generic educational materials for local businesses and organizations to use on their website and in stores. (3)
6. Create a webpage on FWC website with all lionfish outreach materials and list of available grants for invasive species. (2)
7. Create a lionfish documentary to be used in schools, at outreach events, and public forums.
8. Work with industry experts to create a lionfish reality series with a catchy title, such as “Invader Haters” to increase outreach.
9. Implement lionfish educational activities across Florida that coincide with the National Invasive Species Awareness Week.
10. Add lionfish education to existing successful education programs, such as FWC’s “Wear It” life jacket program.
11. Create K-12 lionfish labs and/or curriculum, similar to [Ocearch](#) educational materials.

12. Include information for locations to harvest lionfish and links to purchase lionfish gear from FWC's website (for example: to [lionfish.co](http://lionfish.co) website).
13. Expand the use of technology to include lionfish apps and video games to target younger stakeholders.

## Future Directions

FWC Lionfish staff will consider and evaluate all recommendations made during the 2018 Lionfish Summit. Participants were provided with multiple opportunities to provide input, such as through paper evaluations, electronic response programs (iClicker), Q&A sessions following presentations, and facilitated discussions. A summary and analysis of the iClicker survey results and evaluations can be found in Appendices C and D, respectively.

In regard to policy and regulation, FWC Lionfish staff will work to improve clarity and navigation of current state and federal regulations related to recreational and commercial lionfish harvest, permit requirements for removal of lionfish in prohibited or ecologically-sensitive areas, and the use of innovative removal methods. FWC will also increase outreach to inform stakeholders of current regulations, how to navigate the commercial market, and the permit process for the testing and use of innovative harvest methods. Lastly, staff will continue to explore potential modifications to current regulations to facilitate lionfish removal from areas where spearfishing is otherwise prohibited and encourage the growth of commercial lionfish market.

FWC will continue to explore opportunities to support the research and development of innovative harvest methods, ecological and economic impacts, and the socio-economic risk assessment of lionfish. Support for lionfish removal efforts will continue through agency-administered programs such as the Lionfish Challenge and Lionfish Tournament Assistance Program. Staff will consider stakeholder recommendations to improve existing programs such as Reef Rangers and the Harvest Charter Reimbursement program to more efficiently remove lionfish and expend resources.

FWC staff will actively implement the recommendations to improve outreach efforts regarding the state and federal permitting process and navigating the commercial market. FWC will continue to prioritize statewide education and awareness through the “Be the Predator” travelling lionfish booth, “Become the Predator” workshops, and presentations. Staff will refine and enhance new programs such as the Lionfish: Classroom Invasion, which provides education to a younger audience, and the Lionfish Educational Exhibit Program, which ensures accurate messaging at public facilities to a broad audience. Lastly, staff will continue marketing awareness and FWC programs through social media and other innovative advertising tools.

The 2018 Lionfish Summit served as a valuable platform to exchange knowledge and share accomplishments within and beyond the lionfish industry. Controlling the lionfish invasion requires a sustained long-term effort by FWC and its dedicated partners. The primary objective of the FWC continues to be the pursuit of a combination of management, research, and outreach initiatives to achieve the desired future condition of lionfish in Florida as outlined in the agency’s Lionfish Control Plan. Building upon the success of efforts to control lionfish within the invaded range will require a continued collaboration among the FWC, partner agencies, non-governmental organizations, research entities, commercial industries, and dedicated stakeholders.

# Appendix A: Agenda

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## 2018 Lionfish Summit Agenda

October 2-4, 2018

Hilton Cocoa Beach Oceanfront

Hosted by the Florida Fish and Wildlife Conservation Commission

Facilitated by Dr. James Perran Ross, Rocky Point Consulting Firm, LLC

**Goal:** To assess the efficacy of current research, management, control and outreach efforts; prioritize areas for future lionfish control; and improve collaboration across multiple agencies and geographic locations.

**Outcomes:** Provide updates on lionfish research, management, control and outreach efforts since the 2013 Lionfish Summit; ensure continued education of the public through accurate and consistent messaging; identify potential management actions that facilitate lionfish removal; increase participation in lionfish control efforts; and identify priority research to advance current and future control strategies.

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### Tuesday, October 2, 2018

- 11 a.m. – 1 p.m. Registration & Poster Set-up (*Horizons Banquet Room*)
- 1 p.m. – 1:15 p.m. Welcome Address  
*Jim Estes*, Florida Fish and Wildlife Conservation Commission
- 1:15 p.m. – 1:45 p.m. Keynote Speaker  
**Invasive lionfish in the northeastern Gulf of Mexico: Population trends, ecological impacts, and potential mitigation**  
*William Patterson*, University of Florida
- 1:45 p.m. – 2:15 p.m. State Updates  
**Lionfish Outreach and Control**  
*Kali Spurgin*, Florida Fish and Wildlife Conservation Commission

### **Session I: Policy and Regulation**

- 2:20 p.m. – 2:40 p.m. **Adapting in the age of lionfish**  
*Stephen Gittings*, NOAA Office of National Marine Sanctuaries
- 2:40 p.m. – 3 p.m. **A “hands off” management approach to reducing invasive lionfish populations in federal waters of the Gulf of Mexico and south Atlantic: Current strategies and future options**  
*Kelli O’Donnell*, NOAA National Marine Fisheries Service

3 p.m. – 3:30 p.m. Technology Break

3:30 p.m. – 4:20 p.m. **Panel Discussion: Policy and Regulation**  
*Heather Blough, Daniel Ellinor, Stephen Gittings, Kelli O'Donnell*

## **Session II: Control Efforts/Research and Monitoring**

4:20 p.m. – 4:40 p.m. **An ecosystem-based approach to evaluating impacts and management of invasive lionfish**  
*David Chagaris*, University of Florida

4:40 p.m. – 5 p.m. **Invasive lionfish have not significantly affected native fish in Flower Garden Banks National Marine Sanctuary, Gulf of Mexico**  
*Michelle Johnston*, NOAA Office of National Marine Sanctuaries

5:30 p.m. – 7 p.m. **Poster Session and Social – Horizons Banquet Room**  
Sponsored by the *American Sportfishing Association* and the *Fish and Wildlife Foundation of Florida*

## **Wednesday, October 3, 2018**

## **Session II: Control Efforts/Research and Monitoring**

8:30 a.m. – 8:50 a.m. **Fishing down an invasive species: How much effort does it take to reduce local lionfish populations and mitigate their effects?**  
*Christopher Stallings*, University of South Florida

8:50 a.m. – 9:10 a.m. **Density-dependent condition, growth, and cannibalism in invasive lionfish from the northern Gulf of Mexico**  
*Kristen Dahl*, University of Florida

9:10 a.m. – 9:30 a.m. **Efficiency of lionfish removals by divers and traps in the northern Gulf of Mexico**  
*Holden Harris*, University of Florida

9:30 a.m. – 9:50 a.m. **Trends from 10 Years of REEF lionfish derbies**  
*Alli Candelmo*, Reef Environmental Education Foundation

9:50 a.m. – 10:10 a.m. Technology Break

10:10 a.m. – 10:30 a.m. **Understanding the biology and ecology of invasive lionfish: Insights from northeastern Florida**  
*Eric Johnson*, University of North Florida

10:30 a.m. – 10:50 a.m. **Temporal, spatial, and habitat dynamics of invading lionfish (*Pterois spp.*) populations in the eastern Gulf of Mexico as determined by stationary underwater camera arrays**  
*Amanda Tyler-Jedlund*, Florida Fish and Wildlife Conservation Commission

10:50 a.m. – 11:10 a.m. **Mechanical properties and puncture performance of the venomous spines of the red lionfish, *Pterois volitans***  
*Kate Galloway*, Florida Atlantic University

11:10 a.m. – 11:30 a.m. **Determining the etiology of an emerging ulcerative disease in invasive lionfish**  
*Mohammad Shamim Ahasan*, University of Florida

11:30 a.m. – 12 p.m. **Panel Discussion: Control Efforts/Research and Monitoring**  
*Lad Akins, David Chagaris, Eric Johnson, William Patterson, Chris Stallings, Hanna Tillotson*

12 p.m. – 1:30 p.m. **Lunch** (on your own)

### **Session III: Outreach and Education**

1:40 p.m. – 2:00 p.m. **Whole Foods Market: Role in the commercial lionfish market**  
*David Ventura*, Whole Foods Market

2:00 p.m. – 2:20 p.m. **Lionfish hunting: Getting the public involved**  
*Brady Hale*, Texas Lionfish Control Unit

2:20 p.m. – 2:40 p.m. **Increasing the demand for delicious lionfish dishes: Sebastian Lionfish Fest**  
*Kendra Cope*, Indian River County/Coastal Connections

2:50 p.m. – 3:10 p.m. Technology Break

3:10 p.m. – 3:20 p.m. **Florida Sea Grant: Partners in the control and management of invasive lionfish through research, outreach and education**  
*LeRoy Creswell*, Florida Sea Grant

3:20 p.m. – 3:30 p.m. **Lionfish University: Outreach and education initiatives**  
*Stacy Frank and Jim Hart*, Lionfish University

3:30 p.m. – 3:40 p.m. **DNA barcoding of invasive lionfish prey: A student citizen science project**  
*Jeff Eble*, University of West Florida

3:40 p.m. – 3:50 p.m. **Assessment and management of invasive lionfish populations in Bermuda**  
*Gretchen Goodbody-Gringley*, Bermuda Institute of Ocean Sciences

4 p.m. – 4:30 p.m. **Panel Discussion: Outreach and Education**  
*Kendra Cope, Gretchen Goodbody-Gringley, Brady Hale, Rick O'Connor, Alan Peirce, David Ventura*

6 p.m. – 8 p.m. **Lionfish Social – Sea Oats & Sawgrass Banquet Room**  
Sponsored by the *American Sportfishing Association* and the *Fish and Wildlife Foundation of Florida*

## **Thursday, October 4, 2018**

8:30 a.m. – 8:50 a.m. iClicker Survey Exercise

9 a.m. – 9:20 a.m. **FWC Lionfish Control Plan Update**  
**Sarah Funck**, Florida Fish and Wildlife Conservation Commission

9:30 a.m. – 11:30 a.m. **Discussion Groups (Facilitator, Theme)**  
**Sarah Funck**, Policy and Regulation  
**Kent Smith**, Control Efforts/Research and Monitoring  
**Erin McDevitt**, Outreach and Education

11:30 a.m. – 12:30 p.m. Evaluations and Concluding Remarks

### **Adjourned**

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### **Poster Presentations**

1. Alejandro Acosta, Florida Fish and Wildlife Conservation Commission
2. Raven Blakeway, NOAA Office of National Marine Sanctuaries
3. Alison Feeney, Shippensburg University
4. Alex Fogg, Okaloosa County Board of County Commissioners
5. Stacy Frank and Jim Hart, Lionfish University
6. Kate Galloway, Florida Atlantic University
7. Gretchen Goodbody-Gringley, Bermuda Institute of Ocean Sciences
8. Bob Hickerson, Team Frapper
9. Nancy Pham Ho, BioRad
10. Stephanie Mouchbahni-Constance, McGill University
11. Harley Myler, Lamar University
12. Brent Roeder, R3 Digital Sciences
13. Jian Smith, Reef Save Inc.
14. Kara Wall, Florida Fish and Wildlife Conservation Commission

**Note:** The following participants submitted abstracts and were accepted to give presentations, however they were unable to attend the 2018 Lionfish Summit: Raven Blakeway, David Camperman, Charlie Gliwa, Michael Helmholtz, and Vanessa McDonough.

# Appendix B: Presentation Abstracts

(Alphabetical by last name)

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## **Lionfish soundscape and its role in monitoring and controlling lionfish populations in the Florida Keys**

**Author:** Alejandro Acosta, Jessica Keller, Jennifer Herbig, Ariel Wile and John Hunt

**Affiliation:** Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 2796 Overseas Hwy, Suite 119, Marathon, FL 33050

**Presentation Type:** Poster

Coral reefs face many threats, such as pollution, ocean warming, coastal development, overfishing, and invasive species. An understanding of natural reef soundscapes is needed to determine patterns of reef health and how changes in reef structure are reflected in changes in their soundscape. Many species of reef fishes communicate using sound and this is often associated with spawning or courtship, aggressive behavior, hunting or territorial behavior. Lionfish are no exception and have been recorded making noise in laboratory settings. Passive acoustic techniques have been proposed as an effective tool to monitor and identify areas of high fish densities. A passive acoustic station can monitor selected sites for extended periods of time, providing much needed behavioral information such as diel patterns, timing of spawning, and social behaviors of reef fishes and lionfish populations. In this study, we use passive acoustic techniques and ROV surveys to increase the knowledge of lionfish behavior in twofold: a) to validate that lionfish produce sounds in the wild, characterize these sounds and determine whether lionfish respond by aggregating to these sounds, and b) to improve the effectiveness of monitoring and controlling lionfish populations in the Florida Keys.

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## Determining the etiology of an emerging ulcerative disease in invasive lionfish

**Authors:** Mohammad Shamim Ahasan<sup>1\*</sup>, William F. Patterson III<sup>2</sup>, Roy P. Yanong<sup>2</sup>, Salvatore Frasca, Jr.<sup>3</sup>, Kuttichantran Subramaniam<sup>1</sup>, Theresa Cody<sup>4</sup>, Thomas B. Waltzek<sup>1</sup>

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### Presentation Type: Oral

Invasive lionfish (*Pterois volitans/miles complex*) have become the planet's most successful marine fish invader since their introduction in the western Atlantic in the 1980s, now also being widespread in the Caribbean Sea and Gulf of Mexico (GOM). Removal efforts via spearfishing or trapping have been only marginally effective, and natural biological control of lionfish via native predators or cannibalism is considered to be orders of magnitude lower than their intrinsic rate of population increase. Disease may serve as yet another form of biological control, and in the summer 2017 an ulcerative skin disease appeared to be prevalent in lionfish across a broad swath of their invasive range. In this study, our aim was to identify the causative agent(s) of this emerging disease. Lionfish with cutaneous ulcerations were collected throughout 2017-2018 in the GOM. Representative fish were subjected to necropsy, including microscopic evaluation of wet mount preparations, bacteriologic testing, and histopathologic evaluation. Additionally, lionfish skin tissues and/or swab samples were processed for PCR assays targeting known fish DNA viruses and unbiased viral metagenomic analyses. Gross lesions noted in ulcerated lionfish consisted of ulcerations through the skin and into the skeletal muscle. Microscopic evaluations of wet mount preparations of fin, gill, and ulcerative skin lesions did not reveal parasites. Results of bacterial cultures attempted from the leading edge of ulcers, and from kidney, liver, and brain did not consistently yield a pathogen common to all the samples. Histopathological evaluations have yet to identify an inciting pathogen. However, prior histopathologic evaluations of several ulcers demonstrated attempted tissue healing in some sections, suggesting that the initial injury may have occurred sometime (days or weeks) prior to collection of those lesioned fish. Nucleic acid extracts from ulcerated lionfish skin tissues and swab samples were used to build DNA and cDNA libraries for sequencing on an Illumina MiSeq sequencer, and data are currently being analyzed. Identifying the possible cause(s) of this disease may have implications for managing invasive lionfish populations.

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## **An appetite for lionfish: Can Texas support a commercial lionfish fishery?**

**Authors:** Raven D. Blakeway<sup>1</sup>, Glenn A. Jones<sup>2</sup>, Ashley D. Ross<sup>2</sup>, Michelle Johnston<sup>3</sup>

**Affiliations:** <sup>1</sup>Department of Marine Biology, Texas A&M University at Galveston, 200 Seawolf Parkway, Galveston, TX 77551, <sup>2</sup>Department of Marine Sciences, Texas A&M University at Galveston, 200 Seawolf Parkway, Galveston, TX 77551, <sup>3</sup>NOAA Office of National Marine Sanctuaries, Flower Garden Banks National Marine Sanctuary, 4700 Avenue U, Bldg. 216, Galveston, TX 77551

**Presentation Type:** Poster

Indo-Pacific lionfish (*Pterois volitans*) are the first marine invasive fish species to become established in the Atlantic, Gulf of Mexico, and Caribbean regions. Lionfish invaded the Gulf of Mexico in 2009 and their population has since grown exponentially. To-date, there are no systematic removal strategies employed to manage the population, although ad-hoc efforts (i.e. targeted or bycatch spearfishing) occur intermittently. It is evident that a long-term, sustainable (i.e. ecologically and economically viable) tactic is necessary, as an invasive species is impossible to eradicate once established. We developed a conceptual, sustainable lionfish fishery model that aims to balance native ecosystem vitality and economic viability of local communities. Initially, we determined Aruba could sustain two dedicated lionfish fishermen with this model. Because of these results, and the growing concern for the lionfish issue in the Gulf of Mexico, we conducted research in Texas to determine the likelihood of establishing a fishery along the coast. We conducted a detailed survey with Texas Gulf Coast county residents to determine their awareness of lionfish as a threat, level of concern for lionfish in the environment, willingness to eat and pay for the fish, and level of support/confidence for management, as well as investigated lionfish observation reports and removal efficiency of divers. We found that 57% of Texas Gulf Coast residents were willing to consume lionfish, in contrast to 80% in Aruba and 37% along the U.S. Gulf Coast. Additionally, 45% believe a commercial fishery would be good for the economy and environment and 66% have confidence that researchers, fishermen, and managers can successfully manage the invasion. We estimated that the present population of lionfish is likely 10-fold higher than current observations predict based on the structure available for colonization and limited area that has been surveyed to date. Divers that have removed lionfish from Texas waters have a removal efficiency of approximately 75%; however, this increases by 93% with experience level per diver. Our results conclude that given the social support, structure (e.g. artificial reefs, oil rigs/platforms) and natural habitat available for lionfish to colonize, the rate of their expansion/invasion, and success rate of divers, that a lionfish fishery is likely to be one of the few options available for future management in Texas.

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\*Author unable to attend

## **Scrap science: Cultivating young minds to handle unprecedented challenges**

**Author:** David Camperman

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**Presentation Type:** Poster

Since the fall of 2016 high school students at Covenant Christian School in Panama City, Florida, have been actively researching solutions for problems in the Gulf of Mexico. Their primary areas of research in the academic year of 2016-2017 were sea turtle lighting and lionfish reef affinity. Due to the severity of the lionfish invasion and the incredible efforts by numerous organizations to combat it, the students have continued that research into 2017-2018, forming the Covenant Students Investing in Marine Systems group along the way. They have constructed several traps and fish aggregation devices as variations on "Taco" lionfish trap designs from Dr. Steve Gittings. A good amount of their latest constructions came from scrap materials, hence the working title for the presentation. Many of the students have reviewed research from various authors on invasive species, complementing their marine science curriculum in 2017 and biology in 2018, learning about habitat preference, advantageous traits, founder populations, control efforts, mechanical design and more. Excellent subject matter support has been received from Dr. Gittings, and additional support has been received from local dive shops and a machine shop. Students have met with experts Lad Akins, Hanna Tillotson, Kali Spurgin and Allie ElHage and presented to their Congressional Rep. Jay Trumbull during the DEMA Dive-In to the Capitol. They have conducted trap testing permitted by the FWC out of Panama City in the spring of 2017 and 2018 with one active trial. As they look forward to the 2018-2019 year, a driving force of design will be the needs of fishermen in areas with limited machining capability and access to cheap building materials, such as parts of the Caribbean and Gulf beyond the scope of US waters, with the intent of encouraging lionfish harvesting in these areas.

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## **Trends from 10 years of REEF lionfish derbies**

**Authors:** Alli Candelmo and Ashley Yarbrough

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**Presentation Type:** Oral

2018 marks the tenth year that the Reef Environmental Education Foundation (REEF) has organized lionfish derbies to help combat the impacts and promote awareness of this invasive species. During this time, REEF's 42 organized derbies have captured over 23,000 lionfish from more than 1,500 participants. In addition, REEF has sponsored another 40 REEF sanctioned derby events throughout the state of Florida, Atlantic coast and Caribbean, capturing nearly 20,000 more lionfish from over 1000 participants. Many of the derbies have been held in the same locations annually for up to 9 years. We will present analysis of local trends at each of these events including: public participation, catch per unit effort and size distribution of lionfish. It is important to examine the effectiveness of these community-based efforts, incorporating new scientific findings and results from each event. Strategic assessments can ensure that derbies and alternative removal methods have maximum impacts on the reduction of lionfish populations throughout the invaded range. We also want to ensure that these derbies continue to inform, engage and empower the public. As the invasion progresses and the lionfish population adapts and responds to fishing pressure, research efforts should focus on obtaining information that will have tangible impacts and advance management strategies. Alternative fishing methods including lionfish traps and fish aggregating devices are being tested to supplement removal efforts and target deeper habitats. In addition, further research into the predictability of lionfish movement patterns utilizing surveys and acoustic technology will help improve catch per unit effort across the invaded range.

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## **An ecosystem-based approach to evaluating impacts and management of invasive lionfish**

**Authors:** David Chagaris, William F. Patterson III, and Micheal Allen

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**Presentation Type:** Oral

Predation by invasive lionfish poses a threat to native reef fish communities and may disrupt the food webs that support valuable commercial and recreational fisheries. In some areas of the Gulf of Mexico, lionfish densities are among the highest in their invaded range resulting in severe declines in the small reef fishes that they prey upon. Understanding the ecological consequences of lionfish and designing lionfish control strategies that effectively mitigate their impacts over larger spatial scales requires a multi-species food web modeling approach. Over the last three years, Ecopath with Ecosim (EwE) models have been developed to evaluate food web effects and management of invasive lionfish on the West Florida Shelf (WFS) and northern Gulf of Mexico (nGOM). These models integrate data from a comprehensive field survey that included ROV-based assessments of reef fish abundances and collection of dietary data via fish stomach content analysis. The EwE models have been successful at replicating observed trends in lionfish and the associated declines in their prey. In the nGOM model we estimated reef fish recovery patterns with and without the effects of Deepwater Horizon (DWH) and lionfish. The model indicated that for many small demersal reef fishes, lionfish substantially impacted their recovery following DWH. The models are now being adapted to investigate spatially explicit removal strategies, for example to determine the limitations associated depth-restricted recreational spearfishing and to assess the potential benefits from deep water lionfish traps. Future model developments will focus on providing input for management, such as target exploitation rates and frequency and spatial arrangement of directed lionfish removals.

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## **Increasing the demand for delicious lionfish dishes: Sebastian Lionfish Fest**

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**Presentation Type:** Oral

“Besides their prickly exterior, the invasive lionfish pose a deeper threat to our coastal waters. With no predators balancing their population, the number of lionfish has grown into the BILLIONS and they have an enormous appetite for our native fish. These fish consume prey more than half their size and favor fish and invertebrates that are ecologically and commercially important along the Florida’s coastline. Now is the time to restore balance and put a halt to the most rapid marine invasion in history! WE must be the predator! Humans are the best hope for eradicating this pest. Lionfish may be more difficult to catch than other sport game, but the environmental impact is great, and the lionfish taste delicious!”

This is the driving force each year for Indian River County (IRC) staff and non-profit partner, Coastal Connections Inc., to organize the Sebastian Lionfish Fest. This growing event has exploded in the local community of Vero Beach and East Central/South Florida. Tournament registration has increase by 80% and attendance to the festival has over doubled since the first year. By working with local government staff the event has been able to take on a multifaceted approach to bring awareness to residents and visitors of not only the lionfish invasion problem, but staff have been able to promote lionfish research within schools, increase interest in the County’s artificial reef program through the tournament, and most of all, push the demand for a seasonal fishery through the popular chef cook-off. Although the awareness of the invasive lionfish and its detrimental impacts to our coastal habitats is increasing, ultimately pushing the demand to consume more of this fish, currently there are still gaps in the system preventing the growth of the removal efforts and the lionfish fishery. IRC staff have pinpointed these gaps and will present a “Next Step” action plan to focus our conservation efforts on increasing the demand for a seasonal fishery and the transportation of that fish from fisher to dinner plate.

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## **Florida Sea Grant: Partners in the control and management of invasive lionfish through research, outreach and education**

**Authors:** LeRoy Creswell, Martin Main, Laurence O'Connor, and Florida Sea Grant Extension

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**Presentation Type:** Oral

Florida Sea Grant has been an active partner throughout the state to achieve a better understanding of the impacts invasive lionfish (*Pterois volitans/miles*) have on native reef fish communities along the Atlantic coast and the eastern Gulf of Mexico. Sea Grant supports research to evaluate management policies that mitigate those impacts and provides education information and outreach mechanisms to generate public support and foster stewardship in invasive lionfish programs.

FL Sea Grant sponsored research projects attempt to identify the most efficient and cost-effective methods to fish down lionfish numbers so native fish populations can recover and stabilize. They evaluate the effectiveness of using divers and snorkelers competing in fishing derbies and rodeos to reduce lionfish numbers, and to determine which is the most effective of three removal techniques — derbies, traps, or continuous removal.

FL Sea Grant promotes studies to ensure that human consumption of lionfish is safe, such as studies on ciguatera and other potential food-borne illness that may be associated with lionfish and has published and distributed fact sheets publicly.

FL Sea Grant agents routinely provide lionfish educational exhibits at derbies that display live lionfish to demonstrate their morphology and behavior and distribute factsheets and other educational materials authored by FL Sea Grant Extension staff. Lionfish dissection, morphology, and food habits (stomach analysis) are established activities that agents implement in schools, youth marine camps, and 4-H — reaching thousands of students each year.

FL Sea Grant has been an active sponsor of the lionfish special sessions at the Gulf and Caribbean Fisheries Institute and a contributor to its Special Publication — “*Invasive Lionfish: A Guide to Control and Management*” and the GCFI lionfish portal — <http://lionfish.gcfi.org>.

FL Sea Grant will continue to support and promote peer-reviewed research dedicated to the development of strategies to control and manage invasive lionfish in Florida, and its extension faculty are dedicated to maintaining an active public outreach and educational program to disseminate the relevant education tools as they become available.

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## Density-dependent condition, growth and cannibalism in invasive lionfish from the northern Gulf of Mexico

**Authors:** Kristen A. Dahl<sup>1,2</sup>, William F. Patterson III<sup>2</sup>, David S. Portnoy<sup>3</sup>, J. Derek Hogan<sup>3</sup>, and Morgan A. Edwards<sup>2</sup>

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**Presentation Type:** Oral

Invasive red lionfish (*Pterois volitans*) have become well-established among western Atlantic reef ecosystems where they pose substantial threats to native fish communities. Red lionfish (n = 3,655) were sampled across 5 years in the northern Gulf of Mexico (nGOM) to examine effects of sex, habitat type (natural versus artificial reefs), and population density on lionfish body condition (i.e. mass relative to total length) and growth. Lionfish were collected between 2013 and 2017; ages were estimated by counting opaque zones in otoliths. Mean lionfish length and density increased across the study period, with artificial reefs having lionfish densities that were two orders of magnitude greater than natural reefs. Condition was significantly different between habitats and between earlier (2013-2014) versus later (2015-2017) time periods, with fish having lower condition on artificial reefs and during the later time period. Age estimates ranged from 0.2 to 8.07 years, corresponding to birth years between 2008 and 2017. There were significant differences in growth and size-at-age between sexes and habitats, with males attaining larger size-at-age than females and fish growing faster in natural reef habitats. There was also a significant decline in mean size-at-age as a function of fish density for both males and females captured at artificial reef sites. Therefore, both condition and size-at-age displayed density-dependent effects, which was likely a consequence of intraspecific competition. We also report cannibalism on juvenile lionfish in the nGOM, which was first identified from DNA barcoding of unidentifiable, partially digested prey, and later confirmed via microsatellite genotyping. Results of genotyping indicated that 26.3% of prey samples were confirmed as being cannibalized lionfish and indicate density-dependent cannibalism in invasive lionfish as the highest incidence of cannibalism corresponded to high adult lionfish densities. The lack of native western Atlantic predators suggest cannibalism has the potential to influence population dynamics.

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## **DNA barcoding invasive lionfish prey: A student citizen science project**

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**Presentation Type:** Oral

Over the last three years more than 1200 students from seven Pensacola area schools have used DNA-based methods (DNA barcoding) to investigate the diet of northern Gulf of Mexico lionfish. By integrating research and educational objectives, this project improves understanding of the impacts of invasive lionfish while providing an engaging opportunity for students to gain hands-on experience with commonly used molecular methods and concepts. With financial support and training from University of West Florida faculty, student teams dissected donated lionfish and then isolated, copied, and read prey DNA sequences to identify native prey species. Student findings highlight the generalist diet of lionfish, with Vermillion snapper and Round scad making up the majority of identified prey items. The remaining species commonly occur on offshore reefs and sand flats, including economically important Red Snapper, highlighting the potentially significant consequences of the lionfish invasion.

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## **Recreational scuba diver impacts on invasive lionfish populations in the Bahamas**

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**Presentation Type:** Poster

Recreational scuba diving contributes greatly to the economy and tourism of many coastal communities who rely on healthy coral reefs to ensure tourist satisfaction. The introduction of the Indo-Pacific lionfish, *Pterois volitans* and *Pterois miles*, to the Western Atlantic has detrimentally impacted the region. Repeated culling manages the invasive species but can be costly and challenging in remote areas. One of the advantages of tourists' scuba diving on a week-long liveaboard is that it allows passenger to dive in less accessible reefs. Data was collected from April to November 2017 in the Bimini Islands, Bahamas where recreational scuba divers killed 702 lionfish from 37 dive sites. Bivariate and multivariate analyses were conducted on the number of lionfish kills by distance from development, depth of reef, type of environment, and frequency of dives. The results show the significant contributions of a liveaboard with distance away from inhabited areas being the most significant factor in the number of lionfish killed. Above all, the number of kills declined throughout the dive season and thus indicates that a small number of recreational divers can impact the lionfish population. Such results should be considered by marine conservation managers.

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## Monthly growth rate and population structure changes of northern Gulf of Mexico Red Lionfish (*Pterois volitans*) using length-based population model methodologies

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**Presentation Type:** Poster

Since 2010, Red Lionfish (*Pterois volitans*) have become established in the northern Gulf of Mexico (nGOM) and can now be found in higher densities than anywhere else in their invaded range. The nGOM is an ideal location to conduct population-level monitoring due to relatively easy access to large number of samples spatially and temporally. Numerous studies have investigated population structure as a method of assessing the efficacy of removal and control strategies. Similar to other western Atlantic invaded ranges, the nGOM Red Lionfish population structure exhibits a bimodal length-frequency distribution consistent with variable reproductive output; this bimodal distribution allows for annual cohorts to be tracked over time to calculate growth rates. Red Lionfish age and growth has been quantified in the nGOM making a length-based, age-structured population model an appropriate method to calculate high resolution (monthly) growth rates during the warmer seasons when growth rate is greatest. From March 2014 to October 2014, in collaboration with Red Lionfish fishing tournaments being held in northwest Florida, Red Lionfish (n=700-2,233) were collected and measured for total length monthly during a 1-2 day period. Finally, monthly collection of Red Lionfish began in March 2018 (> 16,000 Red Lionfish processed to date) and will continue through December 2019 such that this additional sampling will provide higher resolution monthly growth rates throughout the year as well as to monitor recent changes to the population stemming from a number of environmental and biological events that have likely altered the population structure.

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## **Lionfish University: Education and outreach initiatives**

**Authors:** Stacy P. Frank<sup>1</sup>, James V. Hart<sup>1</sup>, Dr. Stephen R. Gittings<sup>2</sup>

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**Presentation Type:** Oral

The lionfish invasion has not only impacted the biodiversity of the ecosystem in the Caribbean, Gulf Coast and the Southern Atlantic seaboard, but has also given rise to a social movement and a growing community of diverse, unrelated, and unlikely allies around the world.

Recognizing this social phenomenon, and a need for education and outreach, Lionfish University was established with a primary purpose of providing a forum for all things lionfish; to connect organizations and initiatives working in conservation, including trap research in its infant stages, to promote lionfish as a healthy food source and connect supply with demand, to educate divers about medical guidelines for treating lionfish wounds, to provide basic information about lionfish to schools, dives operators, clubs, dive shops, and the general public to raise awareness about the invasion and the consequences to our environment.

In spite of the explosion around lionfish in the last 5 years, there remains a serious lack of awareness about the invasion and the irreparable harm these invaders are causing to marine life, and the ocean's all-important reef systems.

Until State and Federal governments remove restrictions on harvesting lionfish and fund incentives and research projects aimed at curbing and controlling the invasion, the threat to our oceans, our native fish population, and our reef ecosystems, which are essential to our own survival on this planet, will continue.

Lionfish University Education and Outreach initiatives include:

1. Field reporter system – connect people all over the Caribbean, including Andres Hernandez, a father from a small village in Costa Rica who taught his daughter to spear lionfish with him as a source of food for the family and income.
2. The timeline study of a serious lionfish sting causing necrosis and near amputation through treatment and healing.
3. Lionfish University in partnership with Coast Watch Alliance made first grants to Dr. Steve Gittings for his trap design, research and field testing and is now continuing with Holden Harris, et al. with a grant from FWC/NSF. Other groups are now expanding the use of the Gittings trap design with promising results.
4. Lionfish 101 – PowerPoint for threshold audience with little or no knowledge of lionfish and the invasion.
5. Public service announcements, including lionfish as haute cuisine, culling safety, medical treatments, community outreach.
6. Co-sponsored a concert by Little Texas with Coast Watch Alliance to close 2018 Lionfish Removal and Awareness Day.
7. Rare video of grouper open water kill of a lionfish. Story and Lionfish University report with 1 million views on YouTube.

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## **Mechanical properties and puncture performance of the venomous spines of the red lionfish, *Pterois volitans***

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**Presentation Type:** Oral

The red lionfish, *Pterois volitans*, has venomous spines distributed among several fins (13 dorsal, 2 pelvic, 3 anal), which may contribute to their invasion success in the Western Atlantic and Caribbean. Few predators, such as grouper and select species of sharks, are documented to consume lionfish, and there are few proposed biological controls for this species. Dorsal spines are long, needle-like structures, while the pelvic and anal spines are shorter, more robust, and slightly curved. We hypothesize that mechanical properties and puncture performance vary with region due to diverse morphology and spine tapering. We determined mechanical properties (Young's modulus and toughness) of spines through two-point bending tests, and puncture performance. Young's modulus is the stiffness of a material and toughness is the material's ability to absorb energy. The fourth dorsal, left pelvic, and third anal spine were removed for testing. Spines were bent at several point loads to determine mechanical properties and driven into black grouper skin at a ninety-degree angle for puncture testing. Our data show that the anal and pelvic spines have a higher Young's modulus, suggesting they are stiffer than the dorsal spines. Pelvic and anal spines also have a higher toughness, suggesting they can absorb more energy than dorsal spines. Pelvic spines were also the only spines that did not incur any damage (such as bending or breaking) during puncture testing. These data suggest that the pelvic spines may be more effective as a defense system compared to the numerous dorsal spines, which may primarily serve as an intimidation strategy.

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## **Invasive diving: The potential of dive shops as a science-community interface concerning the lionfish invasion**

**Author:** Kate A. Galloway

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**Presentation Type:** Poster

Since 2009, lionfish derbies have removed over 20,000 lionfish with the support of organizations such as FWC, REEF, and Whole Foods Market, which now sell lionfish fillets. While these derbies are an effective educational tool that simultaneously helps control population growth, they are only held in the summer months, limiting lionfish education throughout the rest of the year. Although many dive shops advertise and support these derbies and coordinate derbies of their own, a strong push for lionfish removal and education comes from passionate individual divers. I began a lionfish jewelry project in order to raise awareness and promote my PhD research, which grew in popularity over social media, and eventually sparked attention from individuals at Force-E Scuba. To facilitate broader lionfish outreach, I began working with Force-E Scuba shops March of this year; a partnership that has strongly supported outreach efforts which relate to my research on the biomechanical properties of the venomous lionfish spines. Force-E Scuba held a lionfish jewelry making workshop and informational session about my research, which fourteen people attended.

Force-E is also carrying my jewelry at their Boca Raton location, which continues our collaboration and community awareness of lionfish. This partnership highlights the potential for dive shop and scientific partnerships which help build the lionfish community. The South Florida community has been very enthusiastic in supporting the removal of this invasive species, while supporting their local dive shop and my research endeavors. Furthermore, dive shops and their dedicated patrons can be actively sought out as educational and motivational partnerships to support the removal and additional research of this persistent invasive species.

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## **Adapting in the age of lionfish**

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**Presentation Type:** Oral

Numerous imaginative solutions have been proposed in response to the invasion of lionfish since the population explosion nearly 20 years ago. The breadth and creativity of the response to the invasion has been an exercise in adaptive management, revealing both strengths and shortcomings. Some early responses proved successful and timely. They included changes in state and federal fishing regulations and policies, active removal through lionfish tournaments and regular culling, and education and outreach activities to raise awareness and increase safety. The scientific community, some working with resource management entities and NGOs, responded quickly to provide valuable information on invasion dynamics, impacts to native species, food safety, and response options. Seafood restaurants, distributors, and retailers have shown their readiness to market lionfish, but are constrained by supply shortages and unpredictability. Primary harvesting to date has been by spearfishing and as bycatch in lobster traps. Novel strategies to enhance supply include robotic collectors, modified lobster and fish traps, and lionfish-specific traps. While showing promise, these have been slow to develop and have yet to be implemented on a large scale. Nevertheless, if shown to be effective, such gear offers considerable potential for controlling lionfish densities, as well as economic benefits for fishing communities, and protection for native species of commercial value.

Recent progress on purse trap development has resulted in numerous testing opportunities in a variety of habitats by several research groups. Following initial tests of prototype traps, which demonstrated the feasibility of FAD-based, non-containment curtain traps in selectively harvesting lionfish, several individuals, NGOs, and research groups obtained support and research permits to build and test the traps. Following operational tests on a fishable prototype purse trap, design drawings were provided to these groups and field testing is currently underway. Concurrently, NOAA's National Marine Fisheries Service and the Office of National Marine Sanctuaries completed a joint Programmatic Environmental Assessment, which enables the issuance of permits to commercial fishers and others to test new traps. All these efforts pave the way for continued testing and improvement of purse traps that minimize bycatch, habitat impacts and entanglement risks, and will not ghost fish, if lost.

Future management of lionfish and other invasive marine species will likely rely on multiple harvest technologies and commercialization models. It will continue to draw from a number of creative solutions from numerous user communities. Doing so, however, will require flexibility in governing regulations to facilitate rapid response and innovation, financial backing to engage the research and fishing communities in technology development, and diligent acquisition of data on the effects to native species and ecosystems.

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**Norman's Lionfish: Wholesale lionfish****Author:** Charlie Gliwa, Ryan Chadwick**Affiliation:** Norman's Lionfish, 74 Orchard Street, New York, NY 10002**Presentation Type:** Oral

For the past three years, Norman's Lionfish has been distributing lionfish to national grocery chains, hotels and restaurants across the country. It has been our mission to get lionfish in the culinary spotlight and spread awareness about lionfish. Although we've had great success and have distributed over 20,000 pounds of lionfish to over 16 different states, several award-winning chefs, and major grocery stores, we face daily challenges sourcing and introducing a new species to the public. Our problem isn't demand – we have large restaurant chains and seafood distributors calling daily and requesting massive amounts of lionfish – amounts we're struggling to source at a price point that is accessible for the public.

Norman's Lionfish will present our company's previous work, ideas on how to increase commercial lionfish harvesting and future company plans.

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## **Bermuda outreach and education initiatives**

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**Presentation Type:** Oral

The extent of the lionfish invasion and formation of reproductive populations throughout the invaded range indicates that lionfish are well established in the Caribbean and Western Atlantic. While complete eradication is unlikely, various management agencies have proposed measures to reduce and/or control local populations. The majority of control strategies involve managed manual removal through targeted spear fishing by SCUBA and free divers. Targeted removal by organized volunteers can be successful in controlling local populations, where continued removal of individuals from an area was found to result in an overall reduction of lionfish biomass. However, the capacity of volunteer cullers to target a broad geographic range, including deep reefs where lionfish have been shown to form dense populations, is limited. Thus, in order to maximize the efficiency of control through removal, the commercial fishing industry must be engaged. In Bermuda, we aimed to increase consumer demand for invasive lionfish in order to promote the establishment of a lionfish fishery. Several local restaurants and grocery stores were provided with lionfish on a monthly basis, caught during our research and control efforts. Following a 6-month supply period, these partner vendors were asked to complete questionnaires regarding consumer response to lionfish and profit margins. We found that consumer response was positive, and demand exceeded supply, with profit margins ranging from fair to high. These results will be shared with local fisherman as an incentive to target lionfish as a premier product with the potential to be a profitable catch. As commercial fisherman increasingly target lionfish as a preferred catch, the efficiency of removal will also increase, thereby increasing the efficacy of lionfish management strategies.

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## Assessment and management of invasive lionfish populations in Bermuda

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**Presentation Type:** Poster

The first lionfish recorded in Bermuda was collected in 2000, yet despite being one of the first locations outside the United States to report the presence of lionfish, the abundance of lionfish in shallow reef zones has remained relatively low. However, dense populations of lionfish have been continuously sighted by technical divers at a few select deep (60 m) sites since 2009. Quantitative surveys of lionfish densities began in 2013, where divers assessed lionfish densities as well as prey fish densities on 15 transects along a depth gradient spread across the Bermuda platform. These surveys confirmed that lionfish populations are concentrated at mesophotic depth in Bermuda, where an average density of 250 fish/ha was reported. Such densities are not pervasive across this depth however, with observations ranging from 0 fish/ha at some sites to 1100 fish/ha at others. Inter-site comparisons of possible ecological drivers of variable lionfish densities on mesophotic reefs revealed a strong interactive effect of seawater temperature and prey fish abundances, indicating that cold-water upwelling currents may be fueling the food chain and resulting in high abundances of prey fish and thus lionfish at specific sites. Beginning in 2017, several mesophotic “hot spots” were monitored and culled monthly for a period of 6 months. At each site, surveys were conducted of lionfish densities and prey fish densities, and all lionfish were removed from the sites. Overtime, we saw a reduction in lionfish density at all three sites, however, there was also a corresponding decline in prey fish abundances. Thus, it remains unclear if the reduction in lionfish is due to the impact of continued culling or to seasonal shifts in prey availability. Managing lionfish populations at mesophotic depths presents unique challenges, as they are beyond recreational diving limits. To overcome these challenges, we have incorporated closed-circuit technical diving, baited remote underwater video (BRUVs), and eDNA. We have also worked to develop lionfish specific traps using modified lobster pots, and recently began testing the lionfish trap developed by NOAA on mesophotic sites. We have also worked with Robots in Service of the Environment (RSE) and Atlantic Lionshare Ltd. to test and develop remotely operated lionfish culling devices. Despite these efforts we are still in the early stages of our control efforts and remain reliant on volunteer cullers in the shallows and grant funding from various agencies to support our deep-water efforts. Thus, a key objective of our work is to promote a lionfish fishery in Bermuda, with the goal of increasing public demand to drive the market and encourage local fisherman to target lionfish as a high-end product. As such, we have established relationships with several restaurants and grocery stores to whom we provide all the lionfish caught during our research and control efforts. This has proved widely successful, with demand for lionfish by local vendors now exceeding our capacity to supply. Having approached lionfish management from a variety of angles, continued control will require a broad spectrum of management tools along with consistent monitoring of populations to clearly assess success.

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**Lionfish hunting: Getting the public involved****Author:** Brady Hale, Texas Lionfish Control Unit**Affiliation:** Texas Lionfish Control Unit, Dallas, TX**Presentation type:** Oral

We are all aware that consistent local control methods must be employed in order to keep the lionfish populations down. But how can we really get divers, and the general public to answer the plead from Government, the scientific community and NGO's alike? Divers say they want to help, but are they following through? Can we increase that number of hunters and citizen scientists? Using marketing and psychological principals, this presentation will give you theoretical and practical techniques to increase diver participation across the invaded area.

Brady Hale is the founder of Texas Lionfish Control Unit, a non-profit dedicated to the hunting, education and research of Lionfish. TLCU regularly introduces new divers to lionfish hunting by leading eco-tourism trips from Texas and other states. Brady is also the founder of Beyond 130 Marketing - a digital marketing firm based in Dallas, TX. Brady combines passion of diving and expertise of marketing to encourage others to join the fight against lionfish.

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## Efficiency of lionfish removals by divers and traps in the northern Gulf of Mexico

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### **Presentation Type:** Oral

The negative ecosystem and fishery impacts of invasive lionfish (*Pterois volitans/miles* complex) throughout their invasive range clearly indicate that population control is paramount. The Florida Fish and Wildlife Conservation Commission, partnering agencies, and non-profits have promoted lionfish removals and facilitated the creation of a lionfish fishery. With the development of recreational and commercial fisheries for lionfish, research is needed to quantify the efficiency of different lionfish removal techniques, particularly in deep (>40 m) water. The incorporation of incomplete detection and removal efficiency is critical for developing and evaluating lionfish management targets, as community-level benefits of lionfish removals may be limited from individuals remaining in the system. We evaluated the efficiency of lionfish removals on reefs in the northern Gulf of Mexico (nGOM) via (1) divers spearfishing on artificial reefs and natural reefs and (2) non-containment, curtain traps (NCC traps) deployed near nGOM reefs. Removal efficiency for divers was estimated from depletion models developed from serial removals via spearfishing. Diver detection was also compared for crepuscular and midday time periods. Mean removal efficiency for the first removal event was 87% on artificial reefs and 59% on natural reefs. Contrary to expectations, we found lionfish detection was unchanged between midday and crepuscular periods. Removal efficiency by traps will be estimated using 12 NCC traps deployed near nGOM artificial reefs. Time-lapse cameras units are installed on the traps to assess trap recruitment of lionfish and bycatch four times per day. Capture rates of lionfish and bycatch are being evaluated in relation to soak time, time of retrieval, trap density, and proximity to source reefs. Initial trials have proven successful in attracting lionfish to the trap with minimal bycatch. Continued work will modify and test trap designs and deployment strategies to evaluate the efficacy and impacts of a deepwater fishery for lionfish in the nGOM. Understanding the effectiveness of removals by divers and traps will assist regional efforts to develop the lionfish fishery, control lionfish populations, and benefit native reef fish communities and fisheries.

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**Above SeaHorse Reef****Author:** Michael Helmholtz**Affiliation:** Above SeaHorse Reef, 16812 SE Highway 19, Cross City, FL 32628**Presentation Type:** Poster

Educational Exhibits: Above SeaHorse Reef collects and sells lionfish alive that can be used for outreach and education. We are offering a total kit with installation, so that live educational displays can be easily placed in public locations.

Aquarium Trade: Wholesaler that provides live lionfish to the aquarium trade. Teaching how to harvest alive and keep alive for the aquarium trade, as well as, what their needs are for transport or shipping. In addition, a discussion will be included on licensing needs for selling to a wholesaler like Michael Helmholtz, and how there may be more financial value to the collector, especially the smaller sized ones that have little value in the food industry, but good value in the aquarium trade.

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## **Developing a lionfish-specific trap: The next step in managing this invasion?**

**Authors:** Bob Hickerson, Maria Hickerson, and Gonzalo De La Peña Casares

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**Presentation Type:** Poster

Since the first documented capture of a non-native lionfish off Florida's southeast coast in 1985, lionfish continue to claim more and more territory at an alarming rate. With no significant progress in slowing their advance, scientists and recreational divers are struggling to develop strategies to mitigate this environmental disaster. Many different tools have been developed in an effort to maximize the effectiveness of the individual scuba diver in capturing lionfish, but what about those large lionfish populations beyond the safe reach of scuba? Development of a lionfish-specific trap will greatly aid in their removals in a variety of habitats. With many hundreds of dives logged observing lionfish behaviors in their natural element, we set out to test a number of trap configurations that appeal to them. After hundreds of hours of testing a mix of materials and configurations in several large mesocosm tanks, we are now in the final stages of fabricating and testing a unique device that uses artificial intelligence to trap lionfish and exclude all other bycatch.

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## Understanding the biology and ecology of invasive lionfish: Insights from northeastern Florida

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**Presentation Type:** Oral

Invasive species are organisms that have been introduced to areas where they do not naturally occur, whose establishment causes injury to recipient ecosystems. One such invader, the Indo-Pacific lionfish (*Pterois volitans/miles*) has rapidly invaded the western Atlantic, Gulf of Mexico and Caribbean Sea with documented negative impacts on native ecosystems. To most effectively manage lionfish and mitigate their effects, a detailed understanding of its life history is required. To better understand the life history of this species, we collaborated with a diverse group of stakeholders including local fishermen and dive captains, non-profit organizations, state agencies to collect lionfish from the offshore waters of northeast Florida. The data were used to develop and validate a length-based, age-structured model for lionfish in the region to estimate growth and population structure, characterize the diet of lionfish using DNA barcoding, and quantify levels of mercury in lionfish tissues. The main findings of this work were: (1) lionfish exhibited rapid growth with seasonal variation in growth rates, (2) distinct cohorts were clearly identifiable in the length-frequency data suggesting that lionfish recruit to this region over a relatively short period in summer, and (3) the majority of lionfish were less than 2 years old with no lionfish older than 3 years of age, possibly as a result of an ontogenetic shift of older fish to deeper water, which may provide a reservoir of spawning biomass not accessible to spearfishing, (4) lionfish diet was dominated by finfish including both commercially and recreationally important species, and (5) mercury levels were lower than many other commonly consumed marine finfish, and fall into Florida's least restrictive advisory level. Further, working directly with stakeholders allowed for efficient collection of biological samples at a large spatial scale, fostered communication between researchers and fishermen and facilitated knowledge transfer to managers.

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## **Invasive lionfish have not significantly affected native fish in Flower Garden Banks National Marine Sanctuary, Gulf of Mexico**

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**Presentation Type:** Oral

The Flower Garden Banks National Marine Sanctuary (FGBNMS), located 100-190 km south of the Texas-Louisiana border in the northwestern Gulf of Mexico, consists of three coral-capped banks including East Flower Garden Bank (EFGB), West Flower Garden Bank (WFGB), and Stetson Bank. EFGB and WFGB have been monitored annually since 1989 through a federally supported long-term monitoring program. Invasive lionfish (*Pterois volitans*) were recorded in monitoring surveys for the fifth consecutive year in 2017 but have been observed by divers consistently on the reefs since 2011. It is well known that these invasive predators can negatively affect the abundance of native prey fishes due to their generalist preferences for both habitat and diet.

Therefore, to understand the effect of lionfish on native reef communities at EFGB and WFGB, we quantified reef fish abundance, density, and biomass from 2011 to 2017, as well as analyzed stomach contents for lionfish removed within sanctuary boundaries. This seven-year time series covered the beginning of the lionfish invasion within EFGB and WFGB, allowing for sampling and analysis of the fish community before and after the invasion. Long-term monitoring fish surveys have consistently displayed an abundant and diverse reef fish community at EFGB and WFGB, predominated by the families Labridae and Pomacentridae, and we found no evidence that lionfish have had a negative effect on overall native reef fish density or community composition. The most common species identified as lionfish prey were Bluehead (*Thalassoma bifasciatum*), Cocoa Damselfish (*Stegastes variabilis*), and Red Night Shrimp (*Cinetorhynchus manningi*). Although it is unclear the role Red Night Shrimp play within the marine sanctuary food web, no significant declines were measured in other common prey fish. Even though the lionfish invasion is likely still expanding in the Gulf of Mexico and negative impacts to the reef community may not be recognized for several more years, lionfish densities seven years after the invasion have not caused a measurable impact to native species at FGBNMS. Ongoing study will help clarify how lionfish may influence native species within marine sanctuary boundaries, making the continuation of long-term monitoring programs vital in the detection and documentation of invasive species and time-sensitive management issues.

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## **Presence and abundance of lionfish within Biscayne National Park after Hurricane Irma**

**Author:** Vanessa McDonough

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**Presentation Type:** Oral

Lionfish have been documented to inhabit Biscayne National Park (BNP) since 2009, with their numbers steadily rising and their distribution expanding throughout the first few years of their invasion. Park staff and cooperators have researched the distribution, abundance, and sizes of these fish, and have obtained a thorough understanding of the preferred habitats of lionfish as well as how their abundances and sizes vary spatially across different areas and habitats in the park. After Hurricane Irma swept through BNP in mid-September of 2017, park staff noted a marked decline in lionfish within the Park. Preliminary analyses revealed that lionfish sightings per hour had declined by more than 50% following the passing of Irma, although site-level effects were variable, with post-Irma lionfish sightings declining markedly at some sites but staying fairly consistent at others when compared to pre-Irma values. The observed decline in lionfish sightings has persisted for nearly a year after the hurricane. Preliminary analyses suggested that size patterns across the different habitats has not changed significantly after the hurricane. Possible mechanisms for the post-hurricane observations and discussions of ongoing and new research to better assess the lionfish population within the park will also be discussed.

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## **Lionfish venom elicits pain predominantly through the activation of non-peptidergic nociceptors**

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**Presentation Type:** Poster

The lionfish (*Pterois volitans*) is a venomous species of fish that has invaded the Caribbean and Atlantic Coast of the U.S. In addition to decimating local fish populations, the lionfish administers an extremely painful sting that can be debilitating for up to one month in severe cases. There exists no treatment for those affected due to the lack of knowledge of the venom's pain-causing properties and mechanism of action. In this study, we provide the first characterization of the pain and inflammation caused by lionfish venom and examine its cellular target(s). We studied the short- and long-term pain resulting from intraplantar injection of the venom in mice with behavioral assays. Inflammation was studied with plasma extravasation assays, and expression levels of neuronal activation markers in the spinal cord were examined via immunohistochemistry. Calcium imaging and electrophysiology experiments were performed to identify the venom's cellular mechanism of action. We find that intraplantar injection of the venom causes an increase in pain behavior, which can be eliminated by trypsinizing or boiling it. The venom resulted in a sharp increase in touch sensitivity, without increasing thermal sensitivity. We observed local inflammation and increased activation of spinal cord pain circuits. Calcium imaging and electrophysiology experiments showed that the venom acts on a subset of pain-sensing neurons, specifically the non-peptidergic, TRPV1-negative C-fibers. Our results provide the first characterization of the pain elicited by the lionfish venom, as well as the first demonstration that the venom acts preferentially on a specific subset of pain-sensing neurons.

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## **Assessing environmental impact of artificial reefs using AUVs**

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**Presentation Type:** Poster

Concrete from demolished buildings, roads and bridges has been used extensively in the creation of artificial reefs in the GOM for the benefit of recreational fishermen and divers. These reefs also produce a welcome environment for Lionfish to predate. Concrete in contact with waters typically increases the pH, especially in the first year prior to significant carbonation. This activity helps to lessen the impact of dissolved carbon dioxide in the form of carbonic acid by sequestering it in the hardened cement paste. We are interested in monitoring these effects by measuring pH levels in the vicinity of submerged concrete reefs. This can be difficult using conventional techniques which involves sounding using a surface operated instrument with a sensor mounted on a long cable. Although practical for lakes and inland waterways, the approach becomes untenable with sunken reefs in the GOM.

Our approach involves the deployment of a specialized *Autonomous Underwater Vehicle* (AUV), the pHybot, which is being designed to not only operate autonomously and without a tether to the surface, but also produce a pH cloud of data in the vicinity of the emplaced concrete mass. This report discusses preliminary experiments with open system batch tank testing using pervious concrete specimens of varying young ages to analyze the pH profiles over time in a way that the robot would under open water conditions. The results indicate that the higher pH values remain close to the specimens. These results imply that the use of pervious concrete near waterways will not have a large spatial impact on pH, especially under dynamic conditions. The implication for reef health is that species sensitive to acidification will find welcome relief from reduced acidity in the vicinity of the artificial structure. In addition to reef acidification data, the pHybot will also provide data on species diversity, to include Lionfish, on tested reefs.

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**SeaDog: AUV support for lionfish harvesting****Author:** Harley R. Myler**Affiliation:** Drayer Department of Electrical Engineering, Lamar University, Beaumont, TX 77710**Presentation Type:** Poster

This poster describes a work in progress, the development of the Autonomous Underwater Vehicle (AUV) *SeaDog*. The *SeaDog* is a small, fast and agile AUV capable of performing its mission in excess of recreational diver bottom time limitations during lionfish spearfishing dives. The robot design is biomimetic in that it fulfills a co-robot function to a solo or paired diver team similar to the role that a trained canine performs in a terrestrial hunting scenario. The robot can operate in two modes, survey and hunt. In the survey mode, the robot is launched from a boat at the dive site and it dives down and surveys the benthic plain and identifies lionfish near the bottom. It returns to the boat and is retrieved. Collected video survey data and lionfish identifications are reviewed by the dive team prior to commencing the dive. This mode allows the dive team to select a different area if no lionfish are present. In the hunt mode, the robot is again launched, it dives to a short depth and waits for the divers to join it. The divers can then command it to scout ahead for lionfish and as it locates prey, it optically signals the divers so that they can harvest the lionfish detected. This device is intended to increase the efficiency of the hunt by minimizing diver time spent finding lionfish.

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## **A “hands off” management approach to reducing invasive lionfish populations in federal waters of the Gulf of Mexico and south Atlantic: Current strategies and future options**

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**Presentation Type:** Oral

Invasive populations of the Indo-Pacific lionfish, *Pterois spp.*, adversely impact federally managed and other native species through competition and predation throughout the Southeast Region. Because lionfish have few natural predators in their invasive range, directed fisheries have the potential to effectively control their abundance.

NOAA Fisheries, in collaboration with the regional fishery management councils, manages fisheries in federal waters under the authority of the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act). The primary objective of the Magnuson-Stevens Act is to prevent overfishing and maximize the yield produced by fisheries over the long term. This objective makes sense when applied to native fisheries and sustaining long-term harvest, but directly contradicts the common objective of eliminating as many invasive lionfish as possible. Therefore, lionfish are unsuitable for “hands on” management under the Magnuson-Stevens Act.

The directed harvest of lionfish is currently unregulated in federal waters of the Gulf of Mexico and South Atlantic. Total landings and ex-vessel revenue increased from about 14,000 pounds and \$78,000 in 2012 to 114,000 pounds and \$567,000 in 2016. While an encouraging trend, further expansion of the directed fishery is limited by technical, regulatory, and policy challenges. While lionfish harvest itself is unregulated, the allowable gear for harvesting is restricted to certain devices. To address these challenges, NOAA Fisheries recently completed several programmatic environmental review documents to facilitate the expedited approval of Exempted Fishing Permits (EFP) and Letters of Acknowledgement (LOA). We have issued one EFP and seven LOAs to date that authorize the study of various trap designs to harvest lionfish while reducing impacts to other species and habitat. Additionally, NOAA Fisheries and the Gulf of Mexico Fishery Management Council have granted a request to approve a remotely operated vehicle for lionfish harvest.

NOAA Fisheries strongly supports efforts to design and test gear that could be used to develop commercial scale fisheries for this species because doing so would create a rare win-win opportunity to increase fishing opportunities and the economic viability of our fisheries while reducing the adverse impacts of lionfish populations on our managed species and their ecosystems. At the same time, we need to ensure such fisheries are not compromising hard-earned conservation gains achieved for federally managed fisheries, protected species, and their habitat. The results of these efforts could be used to inform future regional fishery management council action, including the development of regulatory exceptions to current gear restrictions for devices that meet specific conservation criteria and are used exclusively to harvest lionfish.

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## **Invasive lionfish in the northeastern Gulf of Mexico: Population trends, ecological impacts, and potential mitigation**

**Authors:** William Patterson III<sup>1</sup>, Kristen Dahl<sup>2</sup>, Holden Harris<sup>2</sup>, Micheal Allen<sup>1,3</sup>, David Chagaris<sup>1,3</sup>, and Robert Ahrens<sup>1</sup>

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**Presentation Type:** Oral

Invasive lionfish (*Pterois volitans/miles* complex) were first reported in the northern Gulf of Mexico (nGOM) in the summer of 2010, which was during the same time period the Deepwater Horizon Oil Spill (DWH) occurred. Long-term fish community structure data from remotely operated vehicles surveys conducted at nGOM artificial and natural reefs have enabled us to examine reef fish community and trophic shifts following the DWH, and those data also have also been instrumental in tracking the lionfish invasion and estimating its impact on native reef fishes. The abundance of large (>400 mm total length, TL), exploited reef fishes, like snappers and groupers, typically declined by 20-40% in the nGOM the year following the DWH, while small demersal reef fishes (SDRFs), such as damselfishes, wrasses, and cardinalfishes, often declined by >90%. The lack of recovery observed for SDRFs is estimated to have been driven by lionfish densities that increased exponentially through 2015. Lionfish densities have leveled off or declined somewhat since 2015, but SDRF communities have yet to recover. Moreover, negative correlations between lionfish density and that of fishery species, such as red snapper, suggest lionfish could be having negative impacts on species that are too large for them to prey upon when they co-occur on reefs. Density-dependent effects on lionfish condition and growth likely are drive by both inter- and intra-specific competition for prey resources. Rates of lionfish cannibalism estimated with molecular techniques also increase with lionfish density. A series of lionfish removal experiments, via spearfishing or with traps, suggest current harvest levels are too low to mitigate lionfish impacts on nGOM native reef fishes. However, declines in lionfish density between 2017 and 2018 suggest the appearance of an ulcerative skin disease may be providing some measure of natural control. An overview of this recent research and the potential for lionfish mitigation will be presented in this talk, while other presentations will present details of specific studies that inform aspects of this overview, such as those focused on lionfish population dynamics, simulation modeling, removal efforts, and investigating the etiology of the ulcerative disease impacting invasive lionfish.

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## **Fish Trap Extension Kit for invasive lionfish mitigation**

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**Presentation Type:** Poster

NOAA, the Florida Fish and Wildlife Conservation Commission (FWC), commercial fisherman, and others in the southeastern U.S. seek an economical solution that can capture lionfish in large numbers, while eliminating bycatch as well as “ghost fishing.” Commercial spiny lobster traps have proven to be effective at capturing lionfish in large numbers, however, they produce bycatch and are susceptible to ghost fishing. Therefore, R3 Digital Sciences (R3-DS) is developing the Fish Trap Extension Kit (FTEK), an electromechanical device that will extend the capabilities of commercial spiny lobster traps and convert them from indiscriminate traps into “smart traps” capable of targeting specific fish types. To eliminate lionfish bycatch, the FTEK will enable existing commercial spiny lobster traps to autonomously detect, discriminate, and capture lionfish, while preventing other animals from entering the trap. In addition, the FTEK will detect anomalous trap conditions and be able to render a trap inert by permanently closing the trap entrance. This will eliminate the ghost fishing problems associated with conventional fish traps. Finally, the FTEK will be extremely low cost (targeting < \$30 build cost in production-scale quantities), low power (targeting a two-week run-time on the equivalent of 2 x AA batteries), and rugged (targeting an operational depth to at least 300 feet). R3-DS recently completed the first year of a two-year Phase II SBIR contract from NOAA, to develop and test an FTEK Minimum Viable Product (MVP). In addition, we are executing on a contract with the FWC to test the FTEK in deep water concurrent with our SBIR.

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## Evaluating the viability of a novel purse trap design in capturing *P. Volitans* to facilitate the establishment of small-scale local fisheries in the Caribbean Sea

**Authors:** Jian Smith, Sal DeLello, Corey Krosley

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**Presentation Type:** Poster

The Indo-Pacific Red Lionfish, *Pterois volitans*, is a non-native species in the Western Atlantic, Gulf of Mexico and the Caribbean Sea. First spotted in Florida in the 1980's, *P. volitans* spread rapidly after 2000 due to its tolerance of varying habitats, rapid maturation, high fecundity, and lack of predators in its invaded range. Efforts to curb this exploding population and its ecological impacts have increased in recent years and have been successful on local scales but not on larger ones, particularly outside of the United States. This study aims to 1) test the construction, deployment, and retrieval of a novel lionfish purse trap designed by NOAA; 2) determine the most effectual substrate, depth and soak time for the traps; 3) educate local Caribbean communities about the ecological impacts of *P. volitans* and encourage the establishment of a small-scale fisheries. The initial phase of the study took place over a six-week period from mid-August to early September 2018 on the island of Bequia in St. Vincent and the Grenadines. Eleven traps were constructed on the island using local labor and materials. They were deployed along the western side of the island near areas where local fisherman hunt lionfish. Divers observed and recorded the deployment and retrieval of the traps and conducted daily visual inspections over the original 14-day soak period. Initial deployments were 50% successful (i.e., the traps opened properly) while retrievals were 44% successful (i.e., the traps closed when pulled) and landed a total of 6 lionfish. Lionfish were attracted to 80% of the deep-water traps (~100 ft) within 24-48 hours whereas only one (16%) of the shallow water traps (~50 ft) attracted lionfish within the 14-day period. This phase of the study was small in scale and only moderately successful, but revealed minor design flaws that can be corrected, greatly improving operational efficiency and providing small island communities with a cost-effective and efficient way of controlling populations of *P. volitans* in their coastal waters.

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## **Fishing down an invasive species: How much effort does it take to reduce local lionfish populations and mitigate their effects?**

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### **Presentation Type:** Oral

Invasive lionfish pose a serious threat to the integrity of Atlantic marine ecosystems as well as the goods and services that these ecosystems provide. Therefore, it is prudent to develop and implement active lionfish management actions. The current distribution of lionfish across most of the tropical and sub-tropical western Atlantic combined with the wide range of habitats and depths at which they have been found, indicate that complete eradication, or even substantial depletion of the entire invasive lionfish population, is an unrealistic goal. However, efforts to control local lionfish populations may be useful for mitigating their effects in particularly valuable and/or sensitive areas. Numerous such efforts, using a diversity of approaches, are currently underway, but in most cases the efficacy of these efforts at reducing local lionfish populations and mitigating their effects on native species has not been thoroughly examined. Results of studies which have measured the effectiveness of lionfish removals are inconsistent and no studies have been conducted to explicitly examine the level of removal effort necessary to reach specific management goals. With strict limits on the funding and resources available to deal with the lionfish invasion, it is critical that managers have access to meaningful estimates of the level of effort required to reduce local lionfish populations and to mitigate their effects. We conducted a two-year Before After Control Impact (BACI) experiment in Biscayne National Park, Florida, with three levels of lionfish removal frequency (control, monthly, and every four months) to quantify the effects of removals on lionfish abundance and biomass as well as the resulting potential recovery of native fish communities. Compared to controls, monthly removals effectively reduced lionfish abundance by a factor of 0.55 (95% CI: 0.37 – 0.78). However, while the estimated multiplicative effect of monthly removals on lionfish biomass was less than one (0.53), this effect was not statistically significant (95% CI: 0.21 – 1.29). Similarly, the estimated effects of triannual removals on lionfish abundance and biomass were both in the expected direction (abundance: 0.87, biomass: 0.90) but neither effect was significant (abundance 95% CI: 0.57 – 1.32, biomass 95% CI: 0.35 – 2.56). There was no evidence that lionfish removals had an effect on prey-sized (0 – 10 cm TL) native fish abundance ( $p = 0.34$ ), species richness ( $p = 0.97$ ), diversity ( $p = 0.62$ ), or evenness ( $p = 0.60$ ). Results suggest that in the study system, which is characterized by a continuous reef ledge, even our highest level of lionfish removal effort (monthly removals) was not sufficient to cause large reductions in local lionfish populations or mitigate their effects on native fishes.

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## **Temporal, spatial and habitat dynamics of invading lionfish (*Pterios* spp.) populations in the eastern Gulf of Mexico as determined by stationary underwater camera arrays**

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**Presentation Type:** Oral

Lionfish (*Pterois* spp.) in the Gulf of Mexico (GOM) have been documented on natural and artificial habitats, but detailed habitat specifics are not well known. We analyzed four years of co-located side scan sonar and underwater camera imagery collected as part of ongoing reef-fish monitoring efforts by the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute to characterize fine-scale temporal, spatial, and habitat dynamics of invading lionfish populations throughout the eastern Gulf. From 2014 to 2017, a total of 2,503 videos have been analyzed, and lionfish were observed on 56% of them. Total number of lionfish observed ranged from 1 to 78 per video examined. To date, lionfish have been observed on 23 of 30 different artificial and natural reef habitat types identified via supervised classification of side scan sonar mapping data. The frequency of occurrence of lionfish was highest on three natural reef habitats (spring/sink depressions, fracture, and escarpment) and one artificial (chicken transport cages). Catch-per-unit-effort (lionfish per video) was highest on two natural and two artificial reef habitats (spring/sink depressions, chicken transport cages, reef modules, and fracture). The relative frequency of lionfish increased in both the Florida panhandle and the mid-Florida peninsula from 2014 to 2017. In the Florida panhandle there was no difference in lionfish frequency between nearshore and offshore waters, however, in the mid-Florida peninsula lionfish were almost exclusively found in deeper waters. In both regions lionfish were seen more frequently on artificial habitats in deeper waters (38-180 m). Documented spatial and habitat variability in abundance and size composition of lionfish populations may have important implications as scientists and managers assess the long-term implications of the lionfish invasion on native reef-fish populations. In addition, information on habitat preference such as that presented here may aid managers in directing control efforts such as lionfish derbies to maximize their ability to impact lionfish populations at localized scales.

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## **Whole Foods Market: Role in the commercial lionfish market**

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**Presentation Type:** Oral

Whole Foods Market was the first major retailer to bring lionfish to the marketplace in 2016 and to date has sold 70,000 lbs. David has worked tirelessly to partner with the fishing and diving community around the state of Florida to build a network of harvesters and grow awareness and consumer demand by educating customers and the public at large. In addition, with David's leadership, Whole Foods Market has participated in numerous educational and outreach events across the state, including participating as the title sponsor for this year's Reef Environmental Education Foundation (REEF) summer Lionfish Derby Series in 7 cities.

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## **Length and age distributions of invasive lionfish populations on the west Florida shelf**

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As non-native species invade and colonize new environments, populations typically change following well-defined patterns through time. Initially, invading populations display exponential “booms” in abundance and size structure, occasionally followed by a “bust” as populations contract. These population declines typically result from limiting resources, physical disturbances, or increased predation. Depending on the mechanism, these changes can be observed in the biomass, density, or distribution of the invading population. Alternatively, invasive populations may follow logarithmic population growth, asymptotically leveling off as it reaches an equilibrium state. Nearly a decade post-invasion we examine the status of the Lionfish population in Florida waters of the Gulf of Mexico (GOM), and discuss trends in Lionfish age, density, and size. Using long-term data from annual video and trawl surveys, Florida’s Fisheries Independent Monitoring program documented the rapid increase in GOM Lionfish populations starting in 2010. Densities peaked around 2014, and in subsequent years have leveled off despite a continued increase in the proportion of sampling sites within which Lionfish were captured or observed. The higher frequency of occurrence of Lionfish across both survey types suggests that GOM Lionfish populations are continuing to expand into uncolonized habitats. However, Lionfish size and density have not continued to display exponential growth, despite being at levels below the maximums observed in the region. By examining Lionfish population trends through 2017 we provide empirical evidence to support theoretical responses of an invasive population, supplying managers with framework to guide future control efforts.

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# Appendix C: iClicker Survey Results

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During the final day of the 2018 Lionfish Summit, FWC staff gathered stakeholder input on elements related to each of the three themes using an electronic response program, the iClicker. Participants had the opportunity to provide feedback on priority issues while remaining anonymous through the use of an electronic remote system. In addition to creating an environment for participants to give their unbiased opinion, the iClicker program allows the FWC to more efficiently track and analyze stakeholder feedback.

Fifty-one attendees participated in the iClicker session. Participants were asked to respond to 28 multiple choice questions. The iClicker questions were designed to gather valuable information such as demographics of attendees as well as feedback on the status of policy and regulation, perceived efficacy of current FWC programs, identify focus areas for future research and control efforts, and to determine the best method for marketing.

Participants were first prompted to rank their level of agreement or disagreement with statements on the efficacy of current state and federal regulations in supporting removal efforts. Sixty-seven percent of attendees felt that adjustments should be made to the state's no-spearfishing regulations to create exemptions for non-native removals. Over 50% of respondents favored modifications to the commercial harvest, regulations, and licensing requirements, and 80% of participants indicated a high interest in clarifying the state and federal permit processes for the research and development of innovative harvest methods.

Participants were asked to evaluate FWC's control programs by ranking the program's effectiveness based on the following criteria: number of lionfish removed, diver involvement, and expenditure of state resources. The following percentage of participants rated each program as effective: Lionfish Challenge (68%), FWC-sponsored "Become the Predator" excursions (50%), Tournament Assistance Program (81%), tagging component of the Lionfish Challenge (35%), Harvest Charter Reimbursement Program (32%), and Reef Rangers "adopt-a-reef" program (34%).

Participants were asked to evaluate FWC's outreach and educational programs by ranking their effectiveness based on the following criteria: increasing public awareness, stakeholder engagement, and expenditure of state resources. The following percentage of participants rated each program as effective: Lionfish Educational Exhibit Program (70%), Classroom Invasion program (83%), "Be the Predator" outreach and education booth (82%), and "Become the Predator" workshops (75%).

Participants were asked to identify research areas that are of highest priority for further investigation. Innovative harvest methods were identified as a high priority from 80% of participants, followed by ecological impacts (64%), economic impacts (52%), reproduction (48%), and population estimates (41%).

Lastly, 70% of respondents selected social media as the most effective advertising medium for increasing awareness about lionfish.

# Appendix D: Evaluations

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Lionfish Summit participants were asked to complete an evaluation following the event. Of the 121 participants, 50 evaluations were submitted. The following discussion summarizes the feedback received.

Eighty-eight percent of participants believed that the Eventbrite Summit registration and event communication was effective. Most participants (97%) believed that the Summit was well facilitated and 92% felt that the format and length of the Summit was appropriate.

Ninety percent of participants felt that the panel discussions were valuable components of the event, and 94% indicated a high satisfaction with the networking opportunities that the event provided. An overwhelming 98% of participants believed that the Summit was a productive use of their time, and 83% of participants indicated that the event increased their knowledge about a subject matter that would be applicable to their future work.

Participants indicated that the panel discussions were a valuable source of information and generation of ideas; and the presence of state and federal agencies helped stakeholders clarify protocols on commercial lionfish harvest and lionfish trap testing. Participants indicated that their future actions include increasing collaboration, streamlining research strategies, and updating outreach materials. Suggestions for future events include refining the structure of discussion groups to enhance productivity; inviting additional stakeholders from the commercial fishing, outreach, and education industries as well as from other countries throughout the invaded range; and increasing the frequency of the Lionfish Summit to facilitate communication and collaboration between stakeholders.

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# Appendix F: FWC Lionfish Program

## Overview 2014 – 2018

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### Outreach Efforts

1. **Outreach messaging guide:** The program developed a guide for outreach and messaging that lists key topics for discussion when speaking with the public, including words to avoid, how to circumvent misconceptions and frequently asked questions. This guide is provided to staff and volunteers who participate in any FWC lionfish outreach event. This ensures that agency messaging remains factual and consistent to prevent misinterpretation and provide accurate information to the public.
2. **Educational brochure:** FWC staff created an educational brochure in 2014 and later updated the material in 2017. Brochures are distributed at all outreach events attended by the FWC Lionfish Control Team and sent to a variety of organizations and businesses for dispersal upon request. The document contains information about lionfish (facts, food quality and safe handling), the invasion (history and ecological threat), statewide control programs and ways to get involved.
3. **Outreach booth:** The traveling “Be the Predator” lionfish education booth is brought to various events with the goal of reaching a large volume of people with the agency’s lionfish messaging. The booth is an exciting platform used to provide information to the public about lionfish, the potential threats of the invasion, and how to participate in lionfish control. In addition to attending lionfish-specific and multi-species fishing tournaments, the booth has also been involved with other conventions and outdoor events such as seafood festivals and educational programs focused on conservation. These venues provide a pathway to engage in conversation with members of the public that have a wide range of backgrounds, knowledge and experiences with invasive species. FWC often supplies raffle items or promotional giveaway items at the booth that are designed to encourage divers and members of the public to continue participating in these removal events as well as spread awareness.
4. **Presentations and workshops:** Scheduled on a per-request basis with local clubs and organizations who are interested in learning more about lionfish and ways to get involved in lionfish control efforts. Oftentimes, small groups such as rotary clubs, fishing organizations, or yacht clubs will hear about the lionfish invasion and request additional information from FWC. For groups of 10 or more people, staff will travel to local meetings to present the potential impacts of the invasion, efforts to control lionfish, and programs that encourage stakeholder involvement. At these presentations, staff demonstrates how to safely handle and fillet lionfish to reduce public hesitancy about participation in lionfish removal activities.
5. **School programs:** The FWC Lionfish Program also developed a youth program geared towards students in grades six through twelve, titled “Lionfish: Classroom Invasion”. Scheduled on a per-request basis, staff travels to schools located statewide to educate students about the lionfish invasion, biology and their potential impacts on native ecosystems. To supplement the presentation, students have the opportunity to dissect a lionfish as well as collect various scientific data and gain an understanding of the value of lionfish research. Staff removes the venomous spines prior to the presentation, so students can safely handle and witness first-hand the voracious lionfish appetite as they categorize the stomach contents found during the dissection. The combination of a presentation and dissection allow the FWC Lionfish Program to use a variety of educational tools to engage the next generation of divers and stakeholders.

Educating students about the lionfish invasion and encouraging their involvement in lionfish removal is a key goal identified by the Lionfish Outreach Team.

6. **Event interactions:** The FWC Lionfish Program continues to expand its reach across the state of Florida. In 2015, the program reached over 7,400 individuals by way of in-person discussion, with an average of 235 people per event (including small-scale occasions such as workshops). In 2016, the program dramatically increased its reach to over 13,200 individuals in one-on-one conversations, during 2017, the program reached over 11,147 people, and during 2018, the programs reached over 8,700 people. It is important to note that these numbers only account for FWC-tracked interactions, however the increased conversations and stakeholder action after these interactions with FWC are much higher.
7. **Media Efforts:** FWC staff frequently use various media portals to increase awareness and promote programs and control efforts. Examples include the use of FWC press releases and social media posts (via Facebook, Instagram, Snapchat, etc.) as well as interviews and discussion with local and regional news organizations. During 2017 and 2018, staff directly released and/or participated in the production of over 240 articles and posts. This number is a significant underestimate of the media reach because of the high number of subsequent articles that are a result of FWC's media efforts, however this number is difficult to accurately track.
  - a. **Facebook page:** The Reef Rangers Facebook page launched in 2014 to provide a social media platform for the FWC Lionfish Program. The page posts about current lionfish events, articles and research while providing an opportunity for stakeholders to communicate, post photos and videos, and increase awareness about statewide control efforts. As of December 2018, the page had 4,168 likes and 4,263 follows. Posts reach between 3,000 and 8,000 people and the average reach by post type is as follows: video (34,600 people), link (2,600 people) and photo (1,400 people). Statistics on the gender (65% male), age (primarily between 25-50 years old) and location (United States, major coastal cities in Florida) of the people who follow the Reef Rangers Facebook page are generated by Facebook and provide a better understanding of the audience. Lastly, staff also uses Facebook events for the annual Lionfish Removal and Awareness Day festival and tournament. The event page includes information about the festival, highlights sponsors and vendors, and posts photos and videos regarding the festival and tournament. For example, in 2017, the event reached 72,000 people. Staff plans to continue providing accurate and updated news and messaging as well as a positive portal for communication regarding lionfish control efforts. By monitoring the data and feedback from the Reef Rangers Facebook page, staff can remain actively involved with the lionfish community.
8. **Lionfish Removal and Awareness Day:** FWC staff proposed the creation of an annual event to encourage statewide lionfish removal and increased awareness. Lionfish Removal and Awareness Day (LRAD) was created through a resolution at the February 2015 FWC Commission meeting. Lionfish Removal and Awareness Day will be celebrated the first Saturday after Mother's Day each year. The event includes a festival and spearfishing tournament. The festival includes a celebrity chef competition, fillet demonstrations, family-friendly activities, marine conservation booths, diving, fishing and art vendors, and raffle drawings. Lionfish Removal and Awareness Day is considered an immense success by FWC. The volume of participants at the festival and throughout the state of Florida every year indicate a strong public interest in gaining awareness about this invasive species, as well as a desire to engage in lionfish control efforts.

**Table 1.** a. Results of the FWC hosted Lionfish Removal and Awareness Day Festival and GCLC hosted tournament in Pensacola from 2015 through 2017. b. Results of the statewide events occurring on Lionfish Removal and Awareness Day weekend. Results include the number of lionfish removed from the FWC hosted event in Pensacola.

**Table 1a.** Lionfish Removal and Awareness Day – Pensacola Event Results

Year	Number of Attendees	Lionfish Removed
2015	~3,000	877
2016	~7,000	8,089
2017	~4,000	4,018
2018	~750	13,675

**Table 1b.** Results from the statewide Lionfish Removal and Awareness Day events.

Year	Number of Satellite Events	Lionfish Removed
2015	12	>3,600
2016	7	>14,000
2017	8	>12,000
2018	4	>15,400

- Support for lionfish tournaments:** FWC encourages removal of invasive lionfish from Florida’s waters. Localized removal efforts, such as lionfish tournaments, have been shown to be effective in reducing lionfish populations. FWC seeks to increase participation in lionfish removals through outreach efforts and support of lionfish tournaments. To supplement these efforts as well as cater to the increased requests from stakeholders, FWC has allocated assistance funds to encourage lionfish harvest through organized tournaments. Eligible applicants receive funding assistance to support local lionfish harvest through an organized tournament. The amount of funding provided is based primarily on the type of tournament being held and then secondarily the number of participants. Tournaments must have a minimum of 10 participants in order to be granted assistance funding. Participants are defined as divers or saltwater anglers who are registered for the specified tournament, successfully harvest lionfish within the tournament timeline, and turn in their caught lionfish to the respective tournament weigh-in. Funds are provided to successful applicants upon completion of the tournament and submission of a lionfish tournament report and invoice for assistance funds. The report is to include: results from the tournament (including total number of lionfish), itemized list of assistance fund spending, and participant names and contact information.

**Table 2.** Summary of statewide and FWC-sponsored lionfish tournaments from 2014 through July 2017.

Year	Number of Tournaments sponsored by FWC	Total Number of Lionfish Removed
2014	28	17,246
2015	40	14,838
2016	29	27,167
2017	23	24,029
2018	21	20,522

10. **Mobile application:** In 2014, FWC developed a “Report Florida Lionfish” mobile application in which divers could report lionfish sightings and harvests, which could be submitted along with a picture of their catch. The application was originally an expansion of the Reef Rangers lionfish control program in order to merge the two databases. In 2016, staff decided to deactivate the mobile application to prioritize participation in the Reef Rangers control program. Furthermore, the various portals for stakeholders to report lionfish have become saturated.
11. **“Become the Predator” Lionfish Workshops:** One of the primary goals of the Lionfish Outreach Program is to encourage stakeholders to remove lionfish from Florida waters whenever possible. Because the current, most-effective method to harvest lionfish is by diver removal via spearfishing, FWC implemented a program in 2016 to address increased demand for divers to safely and confidently remove lionfish. The “Become the Predator” program includes a presentation and a lionfish excursion. The presentation educates divers on lionfish, the invasion, statewide control programs, harvest equipment, collection techniques and includes a fillet demonstration. The formal PowerPoint presentation includes current messaging in order to reduce confusion and misinformation regarding lionfish control efforts. Staff provides educational materials and promotional items for distribution as well as harvest equipment for demonstration. The lionfish excursion provides an opportunity for divers to receive a hands-on, field experience harvesting lionfish. The excursion is typically a two-tank offshore dive on natural and artificial reef habitat with abundant lionfish. Staff provide additional guidance on harvest equipment, collection techniques, basic lionfish hunting tips and four sets of a ZooKeeper Lionfish Containment Unit and polespear for use by divers without proper equipment. Lionfish removed on the excursion are measured (total length) and recorded. Prizes are awarded to the divers that harvest the most lionfish, largest lionfish and smallest lionfish and post-event surveys are distributed for divers to provide feedback on the program. The workshops are hosted by a dive shop, dive charter, or any other interested and affiliated diving organization. The presentations are typically held at a dive shop or location that is also open to attendance by the public. Ideally the divers on the excursion have advanced certifications, experience diving offshore, and little to no experience harvesting lionfish.

**Table 3.** Summary of “Become the Predator” Lionfish Workshops in 2016 and 2017.

Date	City	Presentation Host	Excursion Host	Total Number of Participants	Total Number of Lionfish Removed
10/2016	Jacksonville	Offshore Dive Charters	Offshore Dive Charters	14	465
10/2016	Key Largo	Divers Direct	Divers Direct	35	31
10/2016	Pensacola	MBT Divers	Due South Custom Charters and H2O Below	37	104
01/2017	Pensacola	Dive Pros	Niuhi Dive Charters	38	100
04/2017	Deerfield Beach	Dixie Divers	Dixie Divers	33	72
05/2017	Panama City Beach	Diver’s Den	Diver’s Den	19	366
06/2017	Destin	Discovery Dive World	Sea Pal Dive Charters	30	17

12. **Market development:** With increasing interest in lionfish throughout the invaded range, there has been a rise in demand for lionfish in the seafood market. Harvest via SCUBA diving is primarily the most effective method to remove lionfish, but it is time consuming and expensive compared to conventional commercial fishing methods, leading to a sporadic rather than consistent supply. FWC encourages the public to get involved in the development of the commercial lionfish market by including a discussion on licensing requirements, safe handling practices and maintaining a database of Florida lionfish wholesale dealers’ purchasing requirements. Increased communication between commercial lionfish harvesters and those Saltwater Wholesale Dealers interested in purchasing lionfish will facilitate increased removals. Figure 1 illustrates the pounds of commercial lionfish harvested for food purposes. FWC encourages commercial harvesters and wholesale dealers to follow all reporting requirements to ensure commercial lionfish landings data are accurate.

**Figure 1.** Commercial lionfish landings from 2010 through 2018 from the state of Florida. Data through November 9, 2018.



13. **Lionfish Education Exhibit Program:** Effective control of invasive lionfish is highly dependent on consistent messaging and outreach efforts from government agencies, businesses, organizations and stakeholders. The collaboration requires the public understand the potential threats from invasive species and their role in preventing and minimizing these impacts. The goal of the program is to increase awareness and ensure consistent, accurate messaging about the lionfish invasion in Florida waters by supporting the creation of lionfish educational exhibits in public facilities across the state. In addition to the financial support, FWC provides content for public facilities to use as a framework for the educational exhibit. The program launched in April 2018 and will continue through June 2019. A total of 13 facilities have applied and been approved to participate and staff are working with the vendors to develop and implement these projects. Exhibits may include aquaria with live lionfish, interactive activities or standard messaging display boards.

**Table 4.** Summary of outreach events attended by FWC staff from 2014 – 2017. Includes total number of events, number of event attendees and lionfish removed (when applicable).

**Table 4a.** FWC Lionfish Outreach events in 2014.

Event Type	Total Events attended by FWC staff	Event Attendees	Lionfish Removed
Festival	5	1,001	N/A
Presentation	1	11	N/A
Workshop	2	101	152
Tournament	4	434	925

**Table 4b.** FWC Lionfish Outreach events in 2015.

<b>Event Type</b>	<b>Total Events attended by FWC staff</b>	<b>Event Attendees</b>	<b>Lionfish Removed</b>
Festival	5	3,874	N/A
Presentation	5	187	N/A
Workshop	10	257	120
Tournament	17	1,296	8,732
Convention/Conference	4	2,207	200

**Table 4c.** FWC Lionfish Outreach events in 2016.

<b>Event Type</b>	<b>Total Events attended by FWC staff</b>	<b>Event Attendees</b>	<b>Lionfish Removed</b>
Festival	6	9,542	N/A
Presentation	13	1,283	N/A
Workshop	9	333	15
Tournament	9	1,008	10,697
Convention/Conference	2	425	N/A
Excursion	3	66	600
School Dissection	4	642	N/A

**Table 4d.** FWC Lionfish Outreach events in 2017.

<b>Event Type</b>	<b>Total Events attended by FWC staff</b>	<b>Event Attendees</b>	<b>Lionfish Removed</b>
Festival	10	7,527	N/A
Presentation	14	515	N/A
Workshop	1	55	N/A
Tournament	8	1,041	8,941
Convention/Conference	5	1,808	N/A
Excursion	4	52	555
School Dissection	3	149	N/A
FWC Staff Dives	12	N/A	1,598

**Table 4e.** FWC Lionfish Outreach events in 2018.

<b>Event Type</b>	<b>Total Events attended by FWC staff</b>	<b>Event Attendees</b>	<b>Lionfish Removed</b>
Festival	18	5,329	N/A
Presentation	14	965	N/A
Workshop	1	50	N/A
Tournament	11	985	17,015
Convention/ Conference	2	738	N/A
School Dissection	3	600	N/A
FWC Staff Dives	7	N/A	819

## Control Efforts

1. **Lionfish Challenge:** To participate in the Lionfish Challenge, participants remove lionfish from Florida waters and submit them via photo or to checkpoints located statewide. Qualified participants receive a t-shirt and commemorative coin, which is valid for an additional spiny lobster per day during the two-day sport season in July. Additional submissions allow participants to win prizes such as a Neritic Lionfish Eliminator pole spear and grip kit, ZooKeeper Lionfish Containment Units, saltwater fishing licenses, gift cards for SCUBA tank air fills, customized tumblers and neck gaiters, lionfish sting heat packs and more. The winner of the 2016 Lionfish Challenge was crowned Lionfish King/Queen and received a lifetime saltwater fishing license, was featured photo on the cover of the January 2017 Saltwater Regulations publication, featured prominently on the FWC Lionfish Hall of Fame on the MyFWC.com website, and recognized at the November 2016 Commission meeting. The 2017 and 2018 Lionfish Challenge were similar to the 2016 program but included the separation of a recreational and commercial harvester category.
  - a. **Tagged-Lionfish Component:** The 2018 Lionfish Challenge included a novel component, which included tagging lionfish with an external dart tag on 50 randomly-selected public artificial reef sites between the water depths of 80-120'. Between 6-8 lionfish were tagged on each reef, for a total of 213 tagged lionfish. Divers that harvested an FWC-tagged lionfish received a customized performance fishing shirt as well as either cash prizes up to \$5,000 or higher-value product-based prizes. Sponsors donated a total of \$25,000 to be used as cash prizes. The goal of the program was to increase statewide removal efforts by providing divers with a greater incentive to harvest lionfish while in search of the valuable tagged fish as well as to provide valuable data on the movement of lionfish on artificial reef habitats. A total of 27 divers harvested 56 tagged lionfish (48 from the Gulf of Mexico and 8 from the Atlantic Ocean) and an additional four tagged lionfish have been harvested since the program ended in September.

**Table 5.** Results of the Lionfish Challenge incentive program from 2016 through 2018.

Year	Number of Participants	Number of Lionfish Harvested
2016	95	16,609
2017	120	26,454
2018	166	28,260

- Panhandle Pilot Program:** The 2016 Panhandle Pilot Program was a stakeholder inspired incentive program that explored the use of resource-based incentives in seven panhandle counties, where lionfish densities tend to be higher. This year-long pilot program began on Lionfish Removal and Awareness Day 2016 (May 14) and concluded the following year on May 19, 2017. To participate in this program, divers had to remove at least 100 lionfish from the waters off Escambia, Santa Rosa, Okaloosa, Walton, Bay, Gulf, and Franklin counties and submit the tails to an FWC-approved checkpoint for verification. For every 100 lionfish turned in, participants had the opportunity to receive an FWC-issued tag for either a red grouper or cobia over the bag limit in state waters. All other seasonal and size regulations remained in effect when using these species tags. One-hundred thirty total tags were available throughout the program, 30 cobia and 100 red grouper. To further encourage lionfish removals from these areas, individuals or teams of divers who submitted 500 lionfish had the opportunity to rename an artificial reef. This opportunity was limited to the first 10 groups that met the requirement.

**Table 6.** Results of the 2016 Panhandle Pilot Program.

Number of Participants	Number of Lionfish Harvested	Number of Cobia Tags Claimed	Number of Red Grouper Tags Claimed	Number of Artificial Reefs Adopted
52	8,975	23	28	8

- Reef Rangers:** FWC initiated the Reef Rangers Lionfish Control Program in 2014 to encourage targeted lionfish removals on Florida’s reefs. The program is designed similarly to the “Adopt-A-Highway” program in which individuals or teams pledge to maintain a section of highway by removing trash and debris. As a participant in the Reef Rangers program, individuals or teams pledge to conduct regular lionfish removals on local reefs of their choice and report these removals on ReefRangers.com. With this localized control effort applied to Florida’s reefs, the Reef Rangers program aims to improve the efficiency of statewide control efforts and mitigate the effects of the invasion on a statewide scale. As of December 2018, 660 people had registered to become a Reef Ranger. For more information or to sign up to be a Reef Ranger, divers can register at ReefRangers.com, sign up using the mobile kiosk at the “Be the Predator” booth, or follow Reef Rangers on Facebook for current news and statewide events. FWC received additional funding in 2016, which was prioritized for three areas: updating the website, improving program involvement and increasing incentives for continued participation.
- Lionfish Harvest Reimbursement Program:** Despite the increase in recreational and commercial harvest of lionfish, existing lionfish populations and recruitment to Florida’s reefs remain high. FWC is asking for assistance from Florida’s divers and dive organizations to increase lionfish

harvesting efforts. The program aims to incentivize dive charters to conduct lionfish harvesting trips in an effort to increase the number of lionfish removed from Florida waters. Vendors will conduct a lionfish harvest trip and be eligible for reimbursement if the total lionfish harvest is equal to 8 lionfish x the total number of divers. The qualifying total harvest is achievable for divers removing lionfish from areas of the state that vary in population density. It also allows for more-experienced harvesters to compensate for those that are less experienced. Vendors will be reimbursed for \$50/diver upon submission of a final report, which includes the trip receipt (including date), name and contact information of divers, and proof of lionfish harvest via a photo of clearly countable fish and either phone or dive computer for date verification. Since the program began in February 2018, 23 vendors have participated, 228 trips have been conducted, and 810 divers have removed 12,297 lionfish from Florida waters.

5. **Innovative Deep-Water Lionfish Control Research Program:**

- a. Technologies for efficiently removing lionfish in depths beyond recreational dive limits (130') are underdeveloped. FWC selected five applied research projects through a competitive process and will provide financial support to design, develop and test lionfish-specific traps, remote operated vehicles and other advanced technologies that have the potential to advance FWC's ability to efficiently remove lionfish from deep-water habitat. The contracts will also strengthen relationships between FWC and various organizations, universities and non-profit groups throughout Florida. FWC selected the following five vendors: University of Florida, Reef Environmental Education Foundation, R-3 Digital Sciences, American Marine Research Company, LLC and Atlantic Lionshare, Ltd. The contracts were executed in Spring 2018 and the projects will be active through June 2019.
  - b. FWC is also supporting the research, development and testing of modified spiny lobster traps in deep-water habitat beyond recreational diving depths to increase lionfish harvest and reduce bycatch. The goal of the research is to identify a trap that would be classified as a lionfish-specific trap. FWC's Fish and Wildlife Research Institute has obtained an Exempted Fishing Permit from NOAA in order to research and test this work in the Florida Keys. FWC has also contracted with the University of Florida to research and test these same objectives in the northern Gulf of Mexico. Research will be conducted through June 2019.
6. **Lionfish Monitoring and Removal within Biscayne National Park:** FWC hired two OPS staff to continue the long-term monitoring and removal efforts of lionfish populations within Biscayne National Park. Staff were hired in August 2018 and will conduct work within the Park through June 2019. The monitoring and control efforts will provide a better understanding of lionfish density and habitat distribution within areas protected from regular fishing pressure as well as strengthen the relationship between state and federal resource managers.
7. **Science Diving Program:** FWC Lionfish Outreach and Control Program staff maintain an active science diving certification through the American Academy of Underwater Sciences. Staff have undergone rigorous scuba diving training and have been approved by the FWC Dive Safety Officer to conduct diving operations in water depths up to 130'. Staff frequently conduct lionfish removal dives from natural and artificial reef habitats throughout the northern Gulf of Mexico as well as occasionally travel to conduct removals from other areas within Florida. Staff collaborate with the Artificial Reef program to conduct lionfish removals from public artificial reef habitats

as well as ground-truth the location and condition of reefs over time. Staff primarily collect lionfish for outreach purposes, such as for the use in school dissections, displays at presentations and workshops, and for the fillets to be prepared by chefs for public consumption at festivals and events. Reports of lionfish with external ulcers and skin lesions in 2017 have required collaboration with the agency Fish and Wildlife Research Institute Fish Health staff to establish collection protocols, reporting efforts and quality control of samples to investigate the potential causes, prevalence and intensity of the lionfish disease.

8. **Nonnative Species Removal Gear Exemption Permits:** In 2014, FWC staff created a Nonnative Species Removal Gear Exemption Permit. The permit provides a mechanism for removal of nonnative marine species from areas where spearfishing is otherwise prohibited by law. No spearing regulations around Florida are in place to protect ecologically sensitive areas as well as mitigate potential public safety issues. Lionfish have been found in several of these no-spearing zones, hence the need for a mechanism by which to remove these individuals. Permits are only issued to organized groups of divers and only valid for a specific date and time to reduce potential misuse of spearing privileges. Since December 2018, 10 gear exemption permits have been issued and executed for lionfish removal across the state of Florida.

**Table 7.** FWC Lionfish Program Summary of Lionfish Removed by Event Type from 2014 through 2018.

<b>Description</b>	<b>2014</b>	<b>2015</b>	<b>2016</b>	<b>2017</b>	<b>2018</b>
Lionfish Challenge	N/A	N/A	16,609	26,454	28,260
Panhandle Pilot Program	N/A	N/A	8,975*	*	N/A
“Become the Predator” Workshops	N/A	N/A	600	555	N/A
Lionfish Tournaments	N/A	12,874	26,951	24,029	20,522
Lionfish Removal and Awareness Day – Pensacola Headquarters	N/A	877	8,089	4,018	13,675
Lionfish Removal and Awareness Day – Satellite Events	N/A	>3,600	>14,000	>12,000	>15,400
Miscellaneous Outreach Events	152	320	15	N/A	N/A
FWC Dives	N/A	N/A	N/A	1,598	939
<b>Total number of lionfish removed as documented by FWC staff</b>	<b>152</b>	<b>17,671</b>	<b>75,239</b>	<b>68,654</b>	<b>78,796</b>

\*Program timeline: May 14, 2016 through May 19, 2017