Maximizing Catch of Lionfish Through Modifications of Wire-Basket Spiny Lobster Traps: An application for an Exempt Fishing Permit

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PURPOSE

The intent of this application is to request an exemption from **50 CFR 622.9(c) (use or possession of a fish trap)**. Lionfish have colonized much of the deeper waters of the Florida Keys. Traps may be one way to manage their population in these waters. The intent of this application is to permit the Florida Fish and Wildlife Conservation Commission to design and test modifications to wire basket spiny lobster traps designed to make them more effective as a lionfish traps while also reducing bycatch relative to the bycatch observed in wire basket spiny lobster traps. The FWC requests this exemption for a time-period of three years.

INTRODUCTION

Lionfish (*Pterois volitans and Pterois miles*) occupy a variety of habitats including mangrove edges and seagrass but are most often found on coral reefs and other hardbottom with relief. (Biggs and Olden 2011, Barbour et al. 2010). The majority of studies to date have focused on coral reef and associated habitats less than 20 m deep. However, lionfish populations have been documented well beyond recreational diving depths and include mesophotic reefs (Lesser and Slattery 2011). Mesophotic coral ecosystems (MCE) represent important habitats which are 30 – 150m depth (Lesser et al. 2009). Eradication of the invasive lionfish is highly unlikely (Barbour et al. 2011).

The only way to minimize the impacts of this invasion is through concentrated and sustained efforts to reduce lionfish numbers at key locations. To date, most removals have been conducted by spearfishing; lionfish derbies are regularly held to remove lionfish, but are limited to scuba diving depths (Barbour et al. 2011, Green et al 2017). Considerably less effort has focused on deep water removal. Though lionfish are occasionally harvested by hook-and-line at various depths (Akins 2012), harvest from deep water has been primarily as bycatch in lobster traps (Morris and Whitfield 2009, Akins et al. 2012, Gleason and Gullick 2014, Lazarre 2016). There is, therefore, an urgent need for technologies that target lionfish in deeper water (Arias et al. 2011), but which leave other species unharmed (Johnston et al. 2015). Numerous technologies have been proposed or are in development, including modifications to existing lobster traps (Pitt and Trott 2013), other traps, hydraulically powered spears, electrocution devices, and modified suction samplers, among others. Most believe that specialized traps could play a significant role (e.g., Gómez Lozano 2013), but they will need to be designed to avoid both bycatch and ghost fishing (lost traps continue to fish) before being accepted and permitted as suitable for lionfish control (Carballo-Cárdenas 2015). So far, only in Bermuda (Pitt and Trott, 2013) and (Gittings, 2017), have tested lionfish trap designs exclusively developed to target lionfish. There is considerable interest among commercial lobster trap fishermen in wire lobster traps, as they are known to successfully trap lionfish (FKCFA, personal communication).

The proposed project will develop and test experimental trap designs and fishing methods to catch the invasive Indo-Pacific lionfish (*P. volitans and P. miles*). The catch and removal of lionfish from US waters is considered the most effective population control mechanism for this species and the use of traps is considered the most effective method of removing lionfish from deep water (> 30 m). The project will also identify potential bycatch of other species and potential effects on habitat by the experimental traps. The development of a lionfish trap would also support future development of a fishery for lionfish.

PROJECT GOALS AND OBJECTIVES

The goal of the proposed project is to develop a trap design and fishing methods to selectively catch lionfish. The evaluation of each trap design will include quantitative assessments of lionfish catch, bycatch, and trap impacts on habitat. All trap designs will be based on the wire spiny lobster trap currently used in federal waters in the lobster fishery. Modifications to the wire lobster traps to improve lionfish catch and reduce bycatch will include modifying 1) the trap entrance location entrance size, and entrance design including Optical recognition technology if feasible, 2) escape gap location and size, and 3) bait types. A few trap designs will be tested at each time and the most successful designs will be modified and retested. Trap designs that show little merit (e.g. low catch of lionfish, or high bycatch) or prove impractical to use, will be discontinued or modified for additional testing. Otherwise, gear testing will be conducted using a balanced random design suitable for comparing the relative catch rate of lionfish, bycatch of lobsters, and bycatch of fish in each trap design (see methods for details). Our aim is to develop a trap and the methods to use that traps that are highly selective for the capture of lionfish with limited additional bycatch.

The proposed project has the following objectives: 1) to compare lionfish catch of multiple modifications and baits of the current wire-basket spiny lobster trap used by some fishermen in the lobster fishery and 2) to compare lobster and fish bycatch these trap designs. Ultimately, we seek to determine an optimal or a suite of optimal approaches to maximize lionfish catch and minimize bycatch.

BACKGROUND

Invasive lionfish (*Pterois volitans*), a species native to the Indo-Pacific, was first detected in Florida in 1985 (Morris et al. 2009) and spread rapidly throughout the tropical Caribbean and subtropical southeast Atlantic coast (Schofield 2010). With the introduction of the invasive lionfish (*Pterois volitans*) to the Atlantic basin, tropical and temperate marine ecosystems face a threat that is thought to be the fastest marine fish invasion epidemic in history (Morris et al. 2009). Prior to their introduction into the Caribbean there have been no other invasive species that have had such a substantial influence on the marine environment (Schofield 2012). While extensive efforts are made to help protect and preserve important reef communities throughout the Florida Keys and the greater Caribbean region, over the last few decades, abundance and diversity in reef communities throughout the Caribbean have seen unprecedented declines due to a combination of anthropogenic stressors. The introduction of the lionfish will only further disrupt ecosystems and force marine communities to contend with an added risk from this invasive predator. It has also changed how reef managers view invasive species, the regional connectivity of marine reefs, and their vulnerability to marine invasions.

The success of lionfish in the Western Atlantic may be explained by a combination of factors. These species are characterized by high reproductive and dispersal capacities throughout the year, (Moyer and Zaiser 1981, Freshwater et al. 2009, Morris 2009, Morris et al. 2011, Betancur-R et al. 2011, Côté et al. 2013, Elise et al. 2015), have high larval survival rates, making possible fast spread and high larval survival rates (Morris et al. 2011, Côté et al. 2013, and Elise et al. 2015), and both juvenile and adult lionfish appear to be habitat generalists (Côté et al. 2013), allowing rapid colonization of large areas. Across the Western Atlantic, the species are found in temperate hard-bottom reefs (Whitfield et al. 2002, 2007), several types of coral reefs (Albins and Hixon 2008, Biggs and Olden 2011, Lesser and Slattery 2011), seagrass beds (Biggs and Olden 2011), mangroves (Barbour et al. 2010 and 2011) and estuarine rivers (Jud and Layman 2012) and were also reported down to 300 m deep by Nemo submarine off Lyford Cay, Bahamas. The Florida Keys have only recently been invaded and prior to 2009 there were no lionfish reports in the Florida Keys (Ruttenberg et al 2012). Recent data also indicates that the northern Gulf of Mexico has been colonized, with sightings in western Florida, Alabama, Louisiana and Texas (Schofield et al. 2011) (Figure 1). In less than 30 years, lionfish have dramatically expanded their non-native distribution range to an area of roughly 7.3 million km^2, encompassing the eastern coast of the USA, Bermuda, the entire Caribbean region and the Gulf of Mexico, and in 2014 lionfish were found on the southeastern coast of Brazil (Ferreira et al 2015).

Local Eradication Efforts

Although there are few documented examples of established marine invasive species with which to compare, there are numerous cases of successful eradication and management of invasive terrestrial species. The threat imposed by a marine invasive species is considered logistically more difficult to manage due to unconstrained territorial boundaries and accessibility limitations, but examples of successful terrestrial eradications and management efforts (Molnar et al. 2008, Simberloff 2009) offer insight into the development of effective management strategies that can be applied in a marine setting. Additionally, the expansion of social media and rise in environmental stewardship among community members shows promise in managing the lionfish invasion at a local level. The collaboration between media, government agencies, stakeholders and various non-governmental organizations (NGOs) has resulted in the creation of active invasive species management programs, and is crucial in the application of future lionfish management programs. Local control efforts are critical for minimizing the negative impact that lionfish have on marine habitats. Currently, removal of lionfish by divers and snorkelers, using hand nets or spears is the main approach used to reduce lionfish numbers. While targeted control can protect and recover the integrity of invaded native communities at local scales (Albins, 2008; Green et al., 2014), the resources for control are substantially exceeded by the scale of the invasion (Green et al., 2017). Green et al, (2017) reported that lionfish were significantly depleted in fished areas immediately following all the derby events they reviewed, and that the frequency needed to sustain suppression below a level predicted to alleviate predation effects differs between regions. For example, they reported that derbies effectively decreased lionfish densities in both the Bahamas and Florida; however, in Florida, lionfish biomass remained at a level at which predation effects were still predicted. The broad distribution and depth range of lionfish (USGS, 2015), dispersal via a long pelagic larval phase (Ahrenholz & Morris, 2010), and high fecundity (Morris, Shertzer, & Rice, 2011), means that removal must be sustained over the long term to suppress the invasion and its impact. These efforts are invaluable for supporting other conservation initiatives, such as management of marine protected areas and fisheries stock rebuilding. The colonization by lionfish of remote, unmanaged, and deeper habitats will continue to stress marine communities. Until new technologies and approaches are developed for controlling lionfish populations, managers must be prepared for long-term intervention.

Traps have been proposed as a method of controlling lionfish in deep water. Several commercial lobster fishermen in the Florida Keys catch thousands of pounds of lionfish each fishing season using traps. Trip ticket records for Monroe county, which includes the waters of the Florida Keys indicate the traps were the predominant method to catch lionfish (Table 1). In Florida several traps are currently used in fisheries. These traps are attractive alternatives for lionfish control because fishermen have experience with these traps, regulations exist for these traps, and these traps meet current accepted standards in fisheries management. However, considerable concern exists for the reintroduction of traps designed to catch fish, even lionfish in Florida and adjacent Federal waters. There appear to be few species of fishes or invertebrates which will not enter fish traps (Munroe, 1971), and lobster traps constructed predominantly of wire catch considerably more fish than standard wood lobster traps (Matthews et al., 1994). Considerable research was conducted on fish traps to reduce bycatch of unwanted species. In the Caribbean, escape vent location, opposite the funnel, and size, 1⅜-inch by 5 ¾ inch vents were generally the most effective in achieving a balance between releasing bycatch while still retaining a high proportion of catch (Olsen and Hill 2013). Smaller mesh sizes in traps caught more unwanted and higher species diversity than larger mesh. Larger 1.5” square mesh caught larger high value fish (Rosario & Sadovy, 1996) which would still be a concern in a lionfish trapping program.

Table 1. Pounds and number of fishermen in Monroe county each year that caught lionfish for the three most common fishing methods. Lionfish landed and counted as individual fish for aquariums were estimated to weigh 0.79 lbs. for inclusion in this table. *Preliminary data for 2017 is subject to revision.

Year	Dive Caught (lbs)	Number of Divers	Hook and Line Caught (lbs)	Number of Fishers	Trap Caught (lbs)	Number of Trap Fishermen
2011	1,643	19	0	0	2,205	4
2012	1,026	27	233	4	9,562	12
2013	1,419	39	1,073	13	10,562	17
2014	755	34	965	7	8,240	22
2015	6,963	41	600	9	4,934	15
2016	6,620	44	2,299	13	5,620	12
*2017	5,671	39	1,951	9	16,347	11

Observations of lionfish catch by wire lobster traps in deep water (> 100 ft.) indicate that a lionfish specific trap could be effective. Commercial lobster traps in the Middle Florida Keys during the 2011-2012 and 2012-2013 baited and fished to catch lobster also caught 42 lionfish per 100 traps (Lazarre 2017). Lionfish were caught in 21.4% of wire lobster traps; yet, considerable exclusivity was observed in traps that caught lionfish. The number of lobsters per trap was lowest when lionfish and other species were found in traps and lobster catch rates were also low (near 1) when only lionfish were found together with lobsters. Catch models suggest that traps with lionfish catch fewer lobster and other fish (Lazarre (2017). Lionfish caught in these traps ranged in total length from 28 mm to 412 mm indicating a broad range of catchability in traps. In Bermuda the traps and practices used by the commercial lobster fishery were successfully modified to increase the catch of lionfish, reduce catch of spiny lobster, and maintain the low levels of finfish bycatch for which the Bermuda lobster trap was developed. (Ward and Luckhurst 1996, Pitt and Trott 2013).

Life History Research in the Atlantic

With more than 112 scientific publications since 2002, lionfish are one of the most studied fish species in the Atlantic region. Research topics within these publications include lionfish identification, distribution, abundance, ecology, movement and life history in the Caribbean and North America (Appendix 1). The number of research publications for lionfish exceeds that of any reef fish in the Atlantic region or in the lionfish's native region during that time. The first publications on lionfish were from the Atlantic coast of North America from 2002-2004, and covered the initial invasive of lionfish. The country with the largest amount of publications is the United States followed by Bahamas with 34 and 33 references respectively. The most predominant topics of research are: monitoring and removal (33 references), followed by ecological impacts/interactions (30 references) and fisheries with 19 references. Lionfish research has become a main topic at local and regional fishery research conferences. For example, the Gulf and Caribbean Fisheries Institute has hosted a lionfish session since 2002 and the number of presentations has increased from 6 in 2002 to 22 oral presentations and 25 poster presentations in 2015. Topics of research include: ecological impacts/interactions, age and growth, mortality, reproduction, early life history, movement, biophysical/environmental parameters, tagging techniques, feeding, fisheries, genetics, monitoring, socio-economics, and removal among others.

Lionfish are classified as generalist carnivores that feed on a wide variety of fishes and crustaceans (Morris and Akins 2009). Lionfish consume prey at high rates, largely during crepuscular periods (Green et al. 2012). Lionfish are extremely tolerant and adaptive to environmental conditions (temperature, salinity, depth, etc.). They have been reported from all major marine seafloor and substrate types within the invaded Atlantic, and they occupy a very wide range of depths (Morris et al 2009). They have no known predators and have a voracious appetite; this paired with their ability to reproduce every four days drives their success (Morris et al. 2009). Lionfish reproduce via broadcast spawning, so eggs and larvae disperse over great distances via geostrophic and wind-driven currents (Ahrenholz and Morris 2010).

Analysis of mitochondrial DNA indicates that two species, the devil firefish (Pterois miles) and the red lionfish (P. volitans), were introduced into the Atlantic (Hammer et al. 2007, Freshwater et al. 2009). These two species are identical morphologically in the Atlantic (Hammer et al. 2007), but in their native range they can be distinguished with meristics; *P. volitans* exhibit one higher count of dorsal and anal fin rays when compared to P. miles (Schultz 1986).

The research covering lionfish life history is extensive, so lionfish samples collected during this project would not be needed life history analysis. However, lionfish captured during the project could be collected and sent to any researchers that need samples for additional studies.

METHODS

The project study area is the water deeper than 30 m in the Florida Keys National Marine Sanctuary (Sanctuary) from Alligator reef to Looe Key (Figure 1). This area encompasses the Atlantic waters to from a depth of approximately 100 ft to 300 ft. Only areas open to commercial lobster fishing will be included in the study area. Both the Sanctuary and the National Marine Fisheries Service have areas designated as closed to commercial fishing and these areas will be avoided. The study area is well known to commercial trap fishermen and these areas are regularly fished for lionfish. Depth finders will be used to identify appropriate habitat to deploy traps. Traps will be preferentially placed in sand. Areas with more than 1-foot relief that are associated with coral and hardbottom habitat will be avoided.

Figure 1. Project area.

Selection of a wire-basket lobster trap for testing was based on its current success in the catching lionfish while being used to harvest spiny lobster (Lazarre, 2016). Observations aboard commercial lobster boats identified wire lobster traps that did not catch lobsters were more likely to catch lionfish (Lazarre, 2016). We will exploit this research result and attempt to develop a trap that excludes or greatly reduces the catch of lobster and other bycatch to better target and increase the catch per trap of lionfish. Because the primary focus of this research is trap development, testing of trap modifications that demonstrate little functionality will be discontinued and the traps may be modified for further testing. All traps will be fitted with biodegradable panels as defined by current State and Federal rules for the lobster traps to prevent long term ghost fishing if traps are lost.

We will test three or four trap modifications (treatment) at each trap deployment. Traps will be deployed connected to a line (string of traps), occasionally referred to as a trawl. The use of a string of traps is the typical fishing method for traps at this depth in the Florida Keys. This fishing method reduces trap loss from buoy cutoff and reduces the amount of vertical lines which are more prone to entangle protected species (Zollett 2009). The number of traps per string will be determined by the boat captain to facilitate the pulling of traps relative to the size of the fishing boat and other operational considerations. We anticipate that most trawl lines will contain 20 traps. However, the maximum number pf traps per trawl will be 32. The trawl will have one trap line from the surface to the end traps of the trawl line for a total of two trap to surface trap ropes. Given the expectation that 20 traps will be deployed per trawl line, the maximum number of ropes will be 10. A maximum of two buoys will be affixed to the rope for surface identification. Trap pulling will occur during daylight hours only. We anticipate fishing these traps year-round and anticipate that there will be a maximum of 40 fishing trips during a year.

Each trawl will contain equal numbers of each treatment and standard wire-basket traps as the control. We intend to fish a total of 100 traps at any given time during the course of this study. We anticipate using a sample size of 25 traps per treatment type. In other words, we anticipate that each trawl line will contain 25 traps of each of three modifications to the wire basket trap and 25 standard wire basket traps for a total of 100 traps. The number of trea may change as we learn more about the variability in lobster catch caused by non-treatment factors. The order of trap treatments in each string will be random within a stratified design. That is, one trap of each modification type in each test will be grouped together along with a control trap and their location within that group randomized followed by a second group of traps placed in a different random order until the appropriate number of traps are placed together in a string. This design is superior to a simple random placement of traps in each string as it provides equal distribution of trap types between strings of traps and between different areas within a string. The need to compensate for influence of each trap on other neighboring traps was identified in previous trap testing research in the lobster fishery (Heatwole et al 1988).

Traps may be deployed as early as July 1, 2018; however, a later start date is more likely. Initial conversations with potential vendors indicate they are highly focused on restoring their gear and fishing extensively early in the upcoming fishing season. Consequently, the actual start date for this project is uncertain. We anticipate that following the first year (July 1, 2018 – June

30, 2019), we will consider continuing this research for 2 more years, depending on study results, obtaining the appropriate permits, and obtaining funds. We anticipate each revision of trap design and fishing methods to occur after approximately three months of trap testing.

Traps will be pulled by a commercial fishing industry partner on their boat on a regular schedule, weather permitting. Pulling refers to the typical method used in the fishery of retrieving a trap. The trap is brought onboard the fishing boat, the contents are removed, and the trap is redeployed to begin fishing again. The amount of time a trap fished is the time between subsequent pulls and is referred to as the soak time. It is expected that soak time will deviate from the planned schedule due to weather and boat maintenance but soak time is not anticipated to exceed 21 days. Commercial fishermen in this region of the keys typically use a two-week soak period. We anticipate that will be the initial approach. Each trap design or bait type will be pulled multiple times to increase the number of replicate observations of catch in each treatment using each trap pulling round as a covariate.

Considerable consultation with commercial fishermen regarding modifications will occur both during trap development and will be ongoing during trap testing. We anticipate testing a suite of modifications and anticipate that the ideas for trap modifications will evolve during this gear development phase of the research. Below is the list of trap modifications that will be considered. If additional modifications come to our attention and we determine they may have merit for testing, we will contact the National Marine Fisheries Service to ensure they are within the requirements of the Lionfish PEA.

1) Trap throat (entrance) location
    a. Top
    b. Side
2) Trap throat type
    a. Standard plastic lobster funnel – existing on traps – will be the control funnel
    b. Wire funnel
    c. Wire funnel with angle
        i. These exact size of funnel modifications is presently unknown. The details will be worked out with the commercial fishermen. Nevertheless, all funnel modification will be smaller than the standard spiny lobster funnel. The intent will be to reduce bycatch.

3) Escape gap location and size,
    a. Vertical and horizontal vents
    b. Cull rings
        i. These will be designed to maximize lionfish catch while substantially reducing bycatch. The exact dimensions will be determined in partnership with the commercial fishermen.
4) Bait types
    a. Live lionfish
    b. Plastic simulated lionfish (Pitt and Trott 2013)
    c. Artificial lures
    d. Fish oil
    e. Empty Trap
    f. Fish Heads and other standard spiny lobster baits

5) Optical Recognition Technology
    a. Fish Trap Extension Kit (FTEK)*

*We have consulted with the developer of the FTEK system., Mr. Brent Roeder. Early prototypes of his optical recognition system are presently being tested under an LOA issued to Steve Gittings. Mr. Roeder indicates that the objectives are to optimize the optical recognition software for the recognition of lionfish. He further expects to be ready for first testing of his devices using our experimental design by Spring 2019. We anticipate adding these FTEK devise to our experiment at that time and will be working with him as needed to further test prototypes.

Processing of Samples and Identification:

All lionfish will be retained unless used in bait testing experiments. All other fish and lobsters will be identified and enumerated. All non-commercially viable discards will be returned to the water as soon as possible. Depending upon our relationship with the commercial vendor, those species that meet the commercial regulations (In-season, above minimun size, etc.) may be retained. See the FWC relationship to the contractor section. Lionfish and fish will be measured to the nearest cm; lobster will be measured to the nearest mm (Standard length for fish, Carapace length for lobster). Representative sub-samples of fish will be collected for species identification verification in the laboratory as needed. All identifications will be made to the species level. The suite of incidental species that we anticipate encountering are listed below (copied from the table listed below). For more details on incidence rates, see Lazarre (2016) Table 4.3 (page 73) and Figure 4.3 (page 79).

SPINY LOBSTER
STONE CRAB
GRUNT
(Blue-striped, Caesar, Cottonwick, French,
Pinfish, Porkfish, Sailor's Choice, Tomtate,
White, White Margate)
SPIDER CRAB
URCHINS COWFISH
(Honeycomb and Scrawled)
HERMIT CRAB
TRIGGERFISH
(Gray, Ocean, Queen)
ANGELFISH
(French, Gray, Queen) TRUNKFISH
PORGY
(Grassy, Jolthead, Littlehead, Red,
Saucereye, Sheepshead)
PUFFERFISH
PARROTFISH
(Blue, Green, Rainbow, Redtail, Stoplight)
GROUPER
(Black, Gag, Graysby, Red, Snowy
FILEFISH
(Orange-spotted, Planehead, Pygmy,
Scrawled, Slender,Unicorn)
ARROW CRAB
HOGFISH

Statistical analysis

We will compare differences in mean catch per unit effort (CPUE; number of fish/trap/day) of lionfish among trap types using one-way analysis of variance (ANOVA; alpha 0.05) or with the Kruskal–Wallis H-test when the ANOVA assumption of homoscedasticity could not be satisfied. Prior to analysis, all data will be compared against a normal distribution using the Levene’s test, and non-normal data will be log10 transformed to meet the assumption of normality. If log transformation does not normalize data sufficiently, then the nonparametric methods will be used. Mean lengths of lionfish will be compared among trap types via a Kolmogorov-Smirnov test.

Relative catch rates (number of animals/trap/day) will be determined for each trap type. Catch rates will be calculated for lionfish, lobsters, and all other fish bycatch combined. Bycatch of other fish may be further subdivided and analyzed if catch rates of species appear relevant. Catch rates will be analyzed as time series to explore potential changes in catch over time particularly for seasonal patterns or declines in catch potentially from ongoing removals and local population depletion. Statistical comparison of catch between trap types will include GLM with the date the traps were pulled as a factor. Regression analysis will be used to evaluate changes in catch over time. Barring the loss of any traps, sample size between trap pull dates will be equal. Additionally, GLM analysis will include testing the effect of lobster and bycatch on the catch of lionfish. Since we cannot control the number of traps that will be observed with lionfish catch only, bycatch of lobster, and bycatch of other fish an unbalanced design is likely for this test. These statistical comparisons will also be used in Phase II to test for difference in bait testing experiments.

Sampling precision and required sampling size

The precision of catch estimates among gears will be estimated by calculating the sampling coefficient of variation, CV_x (= SD/mean, where X = density). Gears that yield high values of CV_x provide relatively imprecise data and require greater sampling effort than gears with low CV_x (Van Den Avyle et al., 1995a).

Verification Studies

If and when time permits, video and still photos of trap deployment and animal behavior in and near traps will be collected using GoPro Hero2 cameras with external controller cards with Cam-Do and deepwater ScoutPro HH2 housings. The GoPros are set to the widest field of view and programmed to take time-lapse photography at a rate of one picture per second. The external controller card plugs into the HDMI port and switches the camera on for 5 seconds every 15 minutes. The series of 5 images is adequate for detecting fish movement, including swimming form and direction. The camera can be attached with cable ties to the float line approximately 4’ above the trap to give a view of the surrounding area or inside the trap. A SeaViewer Drop Camera will be deployed to verify depth sounders appropriately identified trap deployment habitat and help in determining lionfish presence/ abundance in the sampling site if appropriate.

FWC Relationship to Contractor

As stated, the FWC will contract a commercial fisherman with experience fishing within the study area. The contractor will also be required to have experience fishing lobster trawl lines and in the use of wire-basket traps. Additionally, the contractor must have demonstrable experience in the catch and handling of lionfish. At present, the FWC is discussing the nature of the contract with the fisherman. The total number of vessels will be dependent upon the contractor selected. Most contractors have one (1) vessel. Some have more than one. To our knowledge, for those spiny lobster fishermen that fish in the proposed area, the maximum number of vessels is two (2). Hence, we anticipate conducting this experiment from a maximum of two vessels. At least one FWC scientist will be on-board the vessel at all times.

At this point, the relationship between the FWC and the potential contractor is uncertain. On one hand, the FWC does not issue spiny lobster trap certificates (trap tags) to itself. Consequently, there are two approaches that we will consider.

1. Contract a fisherman who will be required to use their spiny lobster trap certificates and traps (as required by the PEA which was developed anticipating applications from commercial spiny lobster fishermen in mind) as part of their bid. In this instance, we would likely incorporate into the specifications the ability to retain individuals of those species that meet the requirements for being legally harvestable.
2. Alternatively, contract a fisherman who would build traps that would be owned by the FWC. In this case, there will be no certificates used and the bycatch discarded.

Discussions are ongoing with our Division of Marine Fisheries Management as to the preferred option. Considerations are cost and what to do with traps after the project is over if we purchase them.

Project impacts on fisheries, marine mammals, endangered species, or EFH

This project is expected to have a very low risk for impacts to fisheries, marine mammals, endangered species, and essential fish habitat. This activity is very small in nature, is being conducted in a location where no marine mammal special zones occur, is outside of the Florida Reef Tract, and is routinely fished for spiny lobster during the open fishing season. Based upon the findings in the Lionfish PEA (Chapter 4), we conclude this project is well within those findings.

Signature of the applicant

John Hunt
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Appendix 1. This table includes 112 references on the classification, distribution, abundance, ecology, movement and life history of lionfish. Included are major lionfish references published from 2002 to 2017 for the Caribbean and North America. Brief annotations and a subject index are provided.

Age Growth and Mortality	**Location**	**Year**	**Description**
Barbour et al 2011	North Carolina, USA	2011	Age, length, natural and fishing mortality for NC lionfish
Darling and Green 2011	Kenya/ Bahamas	2011	Size comparison in native Kenya vs Bahamas
Albins 2013	Bahamas	2013	Lionfish growth rates on experimental reefs
Benkwitt 2013	Bahamas	2013	Density dependent growth rates of lionfish on an artificial reef
Fogg et al 2013	Northern GOM	2013	Length mass relationships and length frequency of lionfish in norther GOM
Akins et al 2014	Bahamas	2014	TL growth measure over time using mark and recapture
Lazarre 2016 (Dissertation)		2016	Life history traits and growth rate estimates
Farquhar 2017 (GCFI:69)	NC USA/ Bonaire	2017	Comparison of age and growth of lionfish from NC vs Bonaire with fish from NC growing older and larger than those in Bonaire
Movement			
Claydon et al 2012	Turks and Caicos Islands	2012	Ontogenetic movement from shallow seagrass and patch reef to deep water habitats by lionfish
Jud and Layman 2012	Florida, USA	2012	High site fidelity of lionfish as observed using mark and recapture in a Florida estuary
Layman and Allgeier 2012	Bahamas	2012	Evidence of high site fidelity based on distinct prey organisms found in gut contents
Akins et al 2014	Bahamas	2014	Site fidelity using visual detection through mark and recapture
Tamburello and Cote 2014	Bahamas	2014	Movement of lionfish based on habitat type using mark and resight approach
Bacheler et al 2015	North Carolina, USA	2015	High site fidelity of lionfish as observed using acoustic tagging
McCallister et al 2017 (GCFI:69)	Florida, USA	2017	High site fidelity of lionfish and peak activity at dusk and dawn suggesting a strong diel component of lionfish activity
Tagging Techniques			

Jud and Layman 2012	Florida, USA	2012	Mark and recapture tagging study
Akins et al 2014	Bahamas	2014	In situ external tagging methods, mark and recapture
Bacheler et al 2015	North Carolina, USA	2015	Ex situ internal acoustic tagging of lionfish
McCallister et al 2017 (GCFI:69)	Florida, USA	2017	In situ internal tagging methods
Biophysical/ Environmental Parameters			
Whitfield et al 2002	Atlantic Coast, USA	2002	Restrictive temperature parameters for lionfish
Kimball et all 2004	Atlantic Coast, USA	2004	Temperature tolerance of lionfish using chronic lethal minimum protocol
Hackerott et al 2013	Bahamas, Cuba, Belize, Mexico	2013	Lower density of lionfish in windward habitats (preference for low energy environments)
Tamburello and Cote 2014	Bahamas	2014	Mark and resight tagging study
Akins et al 2014	Bahamas	2014	Barotrauma susceptibility
Anton et al 2014	Bahamas	2014	Lionfish preference for low energy environments
Jud et al 2014	Florida, USA	2014	Minimum salinity tolerance and tolerance of salinity fluctuations by lionfish
Whitfield et al 2014	North Carolina, USA	2014	Density of lionfish as a function of depth-temperature
Switzer et al 2015	Florida, USA	2015	Special and temporal dynamics of lionfish in GOM, Deep water colonization
Ecological Impacts/ Interactions			
Albins and Hixon 2008	Bahamas	2008	Presence of lionfish on coral reef habitats reduces recruitment of native fish species
Cote and Maljkovic 2010	Bahamas	2010	Predation on native fish species by invasive lionfish
Albins and Hixon 2011	Bahamas	2011	Worst case scenario of overall ecological impacts on coral reef ecosystems
Albins and Hixon 2011		2011	Long term effects of lionfish on coral reef communities
Alexander and Haynes 2011	Bahamas	2011	Impact of lionfish on native species abundance and coral assemblages
Arias et al 2011	Mexican Caribbean	2011	Use of Ecopath-with-Ecosim model to predict impacts of lionfish invasion on a coral reef community
Frazer et al 2012	Cayman Islands	2012	Potential impacts of lionfish on the Little Cayman reef system

Green et al 2012	Bahamas	2012	Changes in biomass of native fishes due to lionfish predation through visual surveys
Kulbicki et al 2012	Atlantic VS Pacific /Indian Oceans	2012	Abundance in invaded habitat is much higher than in native habitat due to lack of predators
Layman and Allgeier 2012	Bahamas	2012	Overlap in diets and competition between gray snapper, schoolmaster and lionfish in Bahamas
Albins 2013	Bahamas	2013	Impacts of lionfish on recruitment, abundance and diversity compared to native predators
Albins and Hixon 2013		2013	Worst case scenario of overall ecological impacts on coral reef ecosystems
Hackerott et al 2013	Bahamas, Cuba, Belize, Mexico	2013	Presence of native competitive predators does not affect biomass of lionfish
Mumby et al 2013	Bahamas/ Caribbean	2013	Relationship between native grouper and lionfish
Cote et al 2013	Western Atlantic/ Caribbean	2013	Direct and indirect ecological impacts observed and anticipated
Anton et al 2014	Bahamas	2014	Competition/ predation by native fishes
Dark 2014 (Master's Thesis)	Florida, USA	2014	Effects of lionfish on the Indian River Lagoon ecosystem
Green etl al 2014	Bahamas	2014	Model to predict effects of lionfish on diverse assemblages of native prey/ ecological effects
Kindinger 2015	Bahamas/ Cayman Islands	2014	Behavioral response to lionfish by three spot damselfish
McTee and Grubich 2014	Indo-Pacific/Red Sea	2014	Native density distribution of p miles and p radiata
Whitfield et al 2014	North Carolina, USA	2014	Native community structure and lionfish as a function of depth-temperature
Garcia-Urena 2015	Colombia	2015	Reef fish community structure in the presence of lionfish in Colombia
Switzer et al 2015	Florida, USA	2015	Increased abundance of lionfish in deep water habitats as documented through use of trawl surveys
Johnston et al 2017 (GCFI:69)	GOM	2017	Lionfish predation and competitive pressure with respect to sympatric distributions to larval sinks

Fisheries			
Albins and Hixon 2011	Bahamas	2011	Consumption of juvenile spiny lobster
Barbour et al 2011		2011	Lionfish fishery/ fishing mortality impact on lionfish population
Morris et al 2011		2011	Nutritional properties of lionfish in terms of human consumption
Kulbicki et al 2012	Atlantic VS Pacific/Indian Oceans	2012	Success of different fishing methods used to catch lionfish
Moore 2012	Bahamas	2012	Anthropology of fishing and the attempt to incorporate lionfish into the Bahamian fishery
Henderson 2012 (Thesis)	Bahamas	2012	Economic and ecological implications of lionfish on the spiny lobster industry
Albins and Hixon 2013		2013	Creating lionfish fishery
Lazarre et al 2014	Florida, USA	2013	Lionfish bycatch in the Florida Keys commercial spiny lobster fishery
Robertson 2014	US VI	2014	Human risk of ciguatera from consuming lionfish
Tremain and O'Donnell 2014	Florida, USA	2014	Mercury levels in Florida lionfish
Huge et al 2014	Florida, USA	2014	Mercury levels in Florida lionfish
Lazarre 2016 (Dissertation)		2016	Lionfish bycatch and response to benthic structures found in the deepwater commercial spiny lobster fishery
Gittings et al 2017		2017	Designs for two types of deep water lionfish traps
Gittings 2017 (GCFI:69)	Florida, USA	2017	Field trials of four prototype non-containment curtain traps for lionfish
Walker et al 2017 (GCFI:69)	Aruba	2017	Determining fishery/market potential lionfish in Aruba
Feeding Habits			
Morris and Akins 2009	Bahamas	2009	Prey species composition and foraging habits of lionfish
Cote and Maljkovic 2010	Bahamas	2010	Lionfish prey consumption rates and foraging strategies
Albins and Hixon 2011	Bahamas	2011	Prey species and consumption
Green et al 2011	Bahamas	2011	Foraging behavior and prey consumption rates in Bahamas
Munoz 2011	North Carolina, USA	2011	Diet composition and prey species of lionfish based on gut content and stable isotope analysis
Cure et al 2012	Pacific vs Atlantic	2012	Comparison of hunting strategy, time spent foraging and prey species in Pacific vs

			Atlantic
Albins and Lyons 2012	Bahamas	2012	Use of water jets via buccal compression to hunt and consume prey
Green et al 2012	Bahamas	2012	Diet composition/ prey species of lionfish through gut content analysis
Layman and Allgeier 2012	Bahamas	2012	Diet composition/ prey species of lionfish through gut contents and stable isotope analysis
Moreno et al 2012	Mexican Caribbean	2012	DNA barcoding of gut contents to identify lionfish prey organisms in Mexican Caribbean
McTee and Grubich 2014	Indo-Pacific/Red Sea	2014	Diurnal cycles of foraging in native's habitats by lionfish
Bejarano et al 2015	Cayman Islands	2015	Lionfish hunting success based on topographic complexity and physical refugia for prey
Rocha et al 2015	Belize	2015	Lionfish preying on critically endangered endemic species of wrasse and potential for extinction
Ellis and Faletti 2016	Florida, USA	2016	Shift in prey organisms of lionfish from teleost to invertebrates in the presence of red grouper
Dahl et al 2017	GOM	2017	Use of mitochondrial genome barcoding of gut contents of lionfish to identify highly digested prey items
Eddy et al 2017 (GCFI:69)	Bermuda	2017	Use of stable isotope analysis to investigate to investigate the feeding ecology of lionfish in Bermuda
Health and Disease			
Anderson and Stoskopf 2011	North Carolina, USA	2011	Hematology and plasma biochemistry for baseline parameters of lionfish health
Bullard et al 2011	North Carolina, USA	2011	Documentation of parasitism of lionfish by intestinal leech
Sikkel et al 2014	Caribbean and Pacific	2014	Low susceptibility of lionfish to Gnathiid isopods in both native and introduced ranges
Loerch et al 2015	US VI	2015	Low susceptibility of lionfish to parasitized could be a reason for their success in Caribbean
Freeman et al 2017 (GCFI:69)	St Kitts	2017	Two microparasites identified in lionfish removed from the waters around St Kitts
Habitat			

Barbour et al 2010	Bahamas	2010	Use of mangrove habitat by lionfish in San Salvador Bahamas
Jud et al 2011	Florida, USA	2011	Lionfish affinity for anthropogenically created habitats in estuarine system
Biggs and Olden 2011	Honduras	2011	Preferential habitat of lionfish in Honduras. Coral habitats preferred by adults and seagrass by juveniles
Claydon et al 2012	Turks and Caicos Islands	2012	Varied habitat use, density based on habitat and ontogenetic habitat use of lionfish
Green et al 2012	Bahamas	2012	Habitat preference of lionfish based on lionfish size
Jud and Layman 2012	Florida, USA	2012	Use of Loxahatchee River estuary habitat by lionfish
Kulbicki et al 2012	Atlantic VS Pacific/Indian Oceans	2012	Comparison of abundance in native habitat vs invaded habitat
Ruttenberg et al 2012	Florida, USA	2012	Abundance by habitat type in the Florida Keys
Hackerott et al 2013	Bahamas, Cuba, Belize, Mexico	2013	Lower density of lionfish in windward habitats (preference for low energy environments)
Mumby et al 2013	Bahamas/ Caribbean	2013	Habitat preference and behavior
Anton et al 2014	Bahamas	2014	Abundance of lionfish based on topographic complexity of reefs
Dark 2014 (Masters Thesis)	Florida, USA	2014	Lionfish in mangrove habitat in Indian River Lagoon
McTee and Grubish 2014	Indo-Pacific/Red Sea	2014	Preferred habitat and habitat use in their native range
Nuttal et al 2014	N GOM	2014	Depth and habitat type of highest density of lionfish in N GOM
Bejarano et al 2015	Cayman Islands	2015	Abundance of lionfish based on topographic complexity and presence of grouper
Genetics			
Freshwater et al 2009	NC USA/ Bahamas	2009	Mitochondrial control region haplotypes used to determine a single source introduction of lionfish
Barbour et al 2010	Bahamas	2010	Genetic testing to determine a single population of lionfish in San Salvador
Betancur-R et al 2011	Western Atlantic	2011	Mitochondrial DNA screening determine relative genetic homogeneity and suggests dispersal from a single source
Barbour et al 2011		2011	Determining efficacy of removals as a control for lionfish population
Betancur-R et al 2011	Greater	2011	Documenting geographical extent, determining progression and analyzing chronology

	Caribbean/ US East Coast		of invasion
Fadilah 2011	Bonaire	2011	Using Bonaire's lionfish sighting and removal methods as a strategy for Trinidad and Tobago
Morris, Shertzer and Rice 2011		2011	Matrix population model to determine needed fishing mortality required to reverse lionfish population growth
Mumby, Alastair and Brumbaugh 2011	Bahamas	2011	Feasibility of grouper as a natural biocontrol for lionfish
Moreno et al 2012	Mexican Caribbean	2012	DNA barcoding to identify species of lionfish in Mexican Caribbean
Frazer et al 2012	Cayman Islands	2012	Effects of targeted removals on a Little Cayman reef
Green et al 2012	Bahamas	2012	Argument for targeted lionfish searches vs SVC or UVC surveys. Variable correction factors used to account for site specific lionfish size and rugosity which increase estimates of lionfish biomass
Morris (ed) 2012		2012	Monitoring and control strategies
Ruttenberg et al 2012	Florida, USA	2012	Protocol for monitoring invasive lionfish population
Cote et al 2014	Bahamas	2014	Behavioral changes of lionfish after repeated removals in the same habitat
Green et al 2014	Bahamas	2014	Model for targeted removal amount to suppress population below levels of ecological change
NOAA lionfish Response Plan 2015-2018	USA	2015	Marine sanctuary lionfish response plan
Selwyn et al 2017	Indonesia, W Atlantic and Caribbean	2017	Estimate of number of colonizing lionfish in introduced area using population genetic model and haplotypes
Monitoring and Removal			
Whitfield et al 2002	Atlantic Coast USA	2002	Introduction of lionfish along the Atlantic coast of the US
Whitfield et al 2007	Atlantic Coast USA	2007	Use of SCUBA surveys and ROV to determine abundance of lionfish along Atlantic Coast from FL to NC
Guerrero and Franco 2008	Dominican Republic	2008	First documentation of lionfish in Dominican Republic
Schofield 2009		2009	Overview and monitoring of the spread of lionfish invasion in the Western Atlantic

Schofield 2010		2010	Updated version of above paper
Lasso-Alcala and Posada 2010	Venezuela	2010	First published report documenting lionfish on the coast of Venezuela
Arias et al 2011	Mexican Caribbean	2011	Using Ecopath-with-Ecosim model to predict level of removals needed to control the lionfish population
Bariche et al 2013	Mediterranean Sea	2013	Documentation of 2 lionfish (P. miles) in the Mediterranean Sea through use of fin ray meristics and gene sequencing
Mumby et al 2013	Bahamas/ Caribbean	2013	Behavioral changes of lionfish inside a marine park where targeted removals take place vs outside the park
Diller et al 2014	Little Cayman	2014	Use of tethering experiment in various habitats to determine if native predators could be conditioned to consuming invasive lionfish
Kindinger 2015	Bahamas/ Cayman Islands	2014	Use of three spot damselfish as biotic resistance towards lionfish
Nuttal et al 2014	N GOM	2014	Use of ROV to document lionfish beyond safe SCUBA diving range
Ferreira et al 2015	Brazil	2015	Documentation of first reported lionfish sighting in Brazil
Switzer et al 2015	Florida, USA	2015	Use of deep water trawl for monitoring lionfish
Lazarre 2016 (Dissertation)		2016	Invasion background, management implications and future work for lionfish
Dahl et al 2016	Florida, USA	2016	Removals of lionfish on artificial habitats in N GOM to mitigates negative effects on native fish
Ellis and Faletti 2016	Florida, USA	2016	Importance of maintaining intact native predator communities in order to ameliorate the negative effects of the lionfish invasion
Johnson et al 2016 (GCFI:69)	Cayman Islands	2016	Comparison of size classes over time of lionfish removed through culling tournaments in the Cayman Islands
Beattie et al 2017	NC, USA	2017	Preliminary evidence for lionfish vocalizations and the possibility of using bioacoustic monitoring to determine lionfish aggregations as a method of control
Green et al	Florida, USA and Bahamas	2017	Efficacy of voluntary culling derbies as a method to suppress lionfish populations
Gittings et al 2017		2017	Designs for two types of deep water lionfish traps
Fogg et al 2017 (GCFI:69)	nGOM	2017	Comparison of population, age and size structure of lionfish among years and in different areas in nGOM based on lionfish derbies and the effect of derbies on these populations
Reproduction/ Larval and early life stages			

Ahrenholz and Morris 2010	Bahamas	2010	Larval duration of lionfish based on otoliths
Morris et al 2011	NC, USA and Bahamas	2011	Lionfish oogenesis and spawn formation
Morris (ed) 2012		2012	Reproductive strategies of lionfish and larval and early life history
Kulbicki et al 2012	Atlantic vs Pacific/Indian Oceans	2012	Relative abundance of lionfish larvae and new settlers
Cote et al 2013	Western Atlantic/ Caribbean	2013	Reproduction, fecundity, Larval dispersal, post settlement dispersal
Lazarre 2016 (Dissertation)		2016	Spawning frequency, larval recruitment and dispersal
Johnston et al 2017 (GCFI:69)	GOM	2017	A forecast of lionfish larval source and sink locations throughout their invaded range using a biophysical computer model

Appendix 2. Trap types.

Wire Basket Spiny Lobster Trap
Dimensions: Length: 31" x Width: 24" x Height: 19"
Wire Mesh Size: 1.5" x 1.5"
Funnel: single lobster funnel 7" x 4"
Biodegradable panel