
BERMUDA LIONFISH CONTROL PLAN



Photo by Ryan Craig

Prepared by the Bermuda Lionfish Task Force

Edited by James Gleason and Helen Gullick

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PREFACE

Bermuda's marine environment attracts many tourists, supports fishing and diving industries, provides a rich resource for research, and brings hundreds of millions of dollars to the island's economy annually. Invasive Alien Species (IAS) such as the lionfish, *Pterois volitans* and *Pterois miles*, are considered one of the major threats to native species and habitats across the western Atlantic region and pose a threat to Bermuda.

Recognising the potential impacts of the lionfish invasion and the urgent need to develop clear recommendations for local control, a special workshop was organised by a team from local government departments and other organisations, including the DEP, DCS, OSF, BIOS, BAMZ, BZS, REEF and NOAA. The Bermuda Lionfish Control Plan Workshop took place in October 2012, at the Bermuda Aquarium, Museum and Zoo with 31 participants representing over 15 organizations from across the island. The workshop was designed to discuss the goals and objectives of a lionfish control plan, formulate an action strategy, and provide a framework to coordinate activities among government and non-governmental agencies, local individuals, businesses and other organizations to control the invasion of lionfish into Bermuda waters. At the end of this workshop, a Bermuda Lionfish Task Force was established to begin work on the plan.

This document represents the first stage of the control plan and is intended to be a working guide to provide a reference for resource managers, policy makers, field workers, outreach coordinators, researchers, fishers, divers, and the general public — who are actively engaged in learning about lionfish and developing local control strategies. As the plan is implemented, it is expected to change based on new information, availability of resources, and the effectiveness of the various action plans.

James Gleason
Chair, Bermuda Lionfish Task Force
Executive Director, Ocean Support Foundation



ACKNOWLEDGMENTS

The Bermuda Lionfish Task Force and the following document would not have been possible without the help and encouragement of Dr. James A. Morris, Jr. of the National Centers for Coastal Ocean Science, NOAA, and J. Lad Akins, Director of Special Projects for the Reef Environmental Education Foundation. James and Lad worked with the planning committee and were the primary facilitators of the Lionfish Control Plan Workshop. Their experience with other jurisdictions across the Wider Caribbean, Florida, and the Gulf of Mexico provided essential guidance to workshop participants as they developed the framework and priorities for the plan. We are very grateful for everyone's contributions.

Next, it is important to recognise the Lionfish Task Force representatives who oversaw the writing of the control plan and the writing team who worked diligently over the past year to organise this document. They had the skills, talents, and experience required to put the plan together. The overall writing team and their contributions are invaluable. The authors also thank the many reviewers of the various plan sections whose comments helped improve the document

— *James Gleason*



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BERMUDA LIONFISH CONTROL PLAN

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Section 1: Introduction

Bermuda's greatest natural resource is its marine ecosystem. Its coral reef system is the northernmost in the Atlantic, with 280 square miles (725 square km) of reef area. The warm waters of the Gulf Stream give Bermuda a very healthy reef system with abundant hard and soft corals, and a great diversity of fishes. Reef fishes attract tourists from all over the world, support a commercial fishing industry, and most importantly, help keep the reef healthy.

The invasion of lionfish has put Bermuda's marine ecosystem in jeopardy, the effects of which could wreak havoc on our commercial fishing industry, and seriously impact tourism and other sectors of the economy. It also poses a public health risk because of the lionfish's 18 venomous spines.

Lionfish were first reported in Bermuda in 1999, their numbers appear to be increasing rapidly, and they are here to stay. In the early 2000s, Bermuda was recognised as one of the leaders in dealing with the lionfish issue, but it has since fallen far behind. Little is known about the size of the lionfish population in Bermuda, where they are located, how they are impacting local fish and invertebrate populations and other critical information. The majority of what we know about lionfish here is anecdotal and has been reported by our fishermen, divers, and the public. Unlike many jurisdictions in the wider Caribbean and western Atlantic, Bermuda has not made a concerted effort to investigate and establish strategies to control the lionfish problem.

The threat posed by lionfish to Bermuda, coupled with the lack of information necessary to mount a campaign to deal with it, moved a number of organizations to action. On October 9th and 10th 2012, a coalition, representing government departments, environmental and scientific organizations, commercial fishermen, the dive community, and other island stakeholders, came together for a Lionfish Control Plan Workshop, organised and hosted by the Ocean Support Foundation in partnership with the Bermuda Aquarium, Museum and Zoo.

The workshop, designed to help Bermuda begin to fashion a plan of action to control this invasive predator, was facilitated by two of the top authorities on lionfish in the western Atlantic, Dr. James Morris of National Oceanic and Atmospheric Administration (NOAA) and Lad Akins of Reef Environmental Education Foundation (REEF).

Workshop participants quickly recognised that the eradication of lionfish would be impossible. Consequently, the aim of the plan would be to mitigate the negative impacts of lionfish by continuous management of their population through targeted and opportunistic removal. It was also acknowledged that any efforts must be ongoing and comprehensive. Consensus was reached by the group on the priorities to form the basis of the lionfish control plan, and by the end of the workshop, a Bermuda Lionfish Task Force was established to oversee work on this plan. Over the succeeding months, a writing team worked on creating the attached lionfish control plan.



This plan is designed to be a working document and is expected to change over time as new information is discovered, strategies are tested, and more resources become available.

Coalition members have already initiated some of the plan components, details of which can be found in Section 4. To support the priority research components of the plan, the Task Force initiated the submission of a Darwin Plus: Overseas Territories Environment and Climate Fund Project Application. The UK Darwin Plus grant, entitled “*Bermuda Invasive Lionfish Control Initiative*”, was subsequently awarded, in April of 2013 and will bring nearly £170,000 over two years to support key research projects that hope to outline the scope of the lionfish problem and set the stage for the development and implementation of aggressive control measures.

These are the first steps toward creating and implementing a comprehensive programme to protect Bermuda from this voracious predator. However, for the plan to be successful, everyone in the community must become involved as active partners in battling the lionfish invasion.



Section 2. Executive Summary

Risks and Challenges presented by the Lionfish Invasion

RISKS

The unprecedented expansion of lionfish threatens the marine ecosystem of Bermuda's reefs, and thus its fishing and tourism industries. The presence of lionfish also presents a public health risk because of the potentially serious injuries to fishermen, divers, snorkelers, swimmers and tourists, delivered by the lionfish's venomous spines that inflict painful stings.

The presence of lionfish threatens the triggering of a cascade effect, with lionfish disrupting the food webs on a reef. For example, as lionfish consume large quantities of juvenile herbivorous fishes (such as parrotfishes), the herbivores' capacity to keep fast-growing algae in check, maintaining the health of the reef, could be reduced.

CHALLENGES

The challenges of managing such a pervasive invasive species are complex. Lionfish are the first marine invasive reef fish species to the region, so there are no previous experiences to draw from or to guide us. We must learn as we go forward, but we can also draw from the experiences of others facing the same threat. Some of the challenges facing Bermuda are similar to those of most other jurisdictions. These are:

- Lack of trained and dedicated personnel – currently, volunteers primarily conduct the control of lionfish
- Lack of awareness by the community of the lionfish invasion and the potential consequences if they are not managed
- Limited information regarding lionfish population density and distribution
- Lack of research data on lionfish biology and ecology, specific to Bermuda
- Limited comprehensive data on native reef fish populations, particularly on deep terrace and fore reefs – this limits an assessment of the impact of lionfish
- Limited funding and other resources
- Lack of technology to access lionfish populations at depths beyond recreational scuba limits – observations in Bermuda and almost all other invaded areas indicate that lionfish are found in large numbers at depth, and effective assessment and control strategies must be developed for this environment
- Lack of strategies and incentives to sustain an ongoing, long-term management programme

The development and implementation of a cohesive long term lionfish control plan is essential if we expect to mitigate the risks and resolve the associated challenges.



Purpose and Scope of the Bermuda Lionfish Control Plan

The purpose of the lionfish control plan is to guide the Bermuda Lionfish Task Force partners, other stakeholders, and the general public, in addressing the long-term effects of lionfish in Bermuda waters. The plan outlines approaches based on the priorities established during the October 2012 Lionfish Control Plan Workshop as the scope of the plan. The five priorities are:

1. Education, outreach and training
2. Research and assessment
3. Detection and removal
4. Monitoring and data gathering
5. Data management

As regards research and assessment, ten key research questions were identified with three of these being deemed of highest priority:

- Lionfish population assessment
- Feeding ecology (what they are eating)
- Baseline assessment of reef fish communities

The research projects to be prioritised are those that will support removal strategies. They will help us to prioritise the areas to be protected (e.g. fish nurseries, MPAs, dive sites, etc.) and set control targets for reducing lionfish populations.

Developing the Lionfish Control Plan and Current Actions

The first major step toward the formalization of a long-term lionfish control plan was the establishment of a coalition of key stakeholders, who have the skills, talents and desire to tackle such a momentous task. This coalition formed a representative body called the Bermuda Lionfish Task Force.

The Task Force comprises of members from government, scientific research and education organizations, the dive community, fishermen, NGOs, and the corporate private sector. Its initial task was to oversee the development of the control plan, utilizing a volunteer writing and editing team.

The next important steps are to engage other institutions, the private sector, and the general public, in supporting the implementation of the lionfish control plan, and to identify the resources needed to ensure the success of the long-term battle against this formidable enemy.

Moving Forward



The potential impacts are real and Bermuda must respond by implementing this plan as soon as possible in order to address the severity and scale of the invasion. This requires the participation of the government, NGOs, public and private sector organizations to develop the funding and other resources necessary for a coordinated response plan to be initiated and fully implemented.

The Bermuda Lionfish Task Force provides a mechanism for coordinating and focusing the efforts of the coalition members in the implementation of all components of the control plan. However, for the plan to have any potential for success, a small, dedicated group of full-time personnel will be required to coordinate plan components, seek out resources, and oversee communications between organizations and the general public. Volunteers, while essential, cannot be the basis for an effective long-term lionfish control plan.

The success of the control plan can also be greatly assisted through partnerships with the broader regional lionfish programmes. This includes the U.S. National Oceanic and Atmospheric Administration (NOAA), the Gulf and Caribbean Fisheries Institute (GCFI), the Caribbean Environment Programme (CEP), the Reef Environmental Education Foundation (REEF), other regional organizations, and the new UK Joint Nature Conservation Committee (JNCC), UKOT Lionfish Initiative. Much can be gained from the work already carried out by these organizations and there are many opportunities for collaboration that will help speed the implementation of Bermuda's lionfish control plan.



Section 3. Background

THE LIONFISH

The exotic lionfish (*Pterois miles* and *Pterois volitans*) are predatory fish belonging to the scorpionfish family Scorpaenidae, and are native to the Indian and Pacific oceans. In the western Atlantic, lionfish can grow to a size of over 18 inches (45 cm) in length, while juveniles may be as small as 1 inch (2.5 cm) or less. The lionfish's body is covered in distinctive red or brown, and white stripes. Fleshy tentacles often project from above the eyes and below the mouth. They have fan-like pectoral fins, and 13 dorsal spines, 9-11 dorsal soft rays, 2 pelvic spines, 3 anal spines, and 6-7 anal soft rays. The venomous spines are shown in red, below.

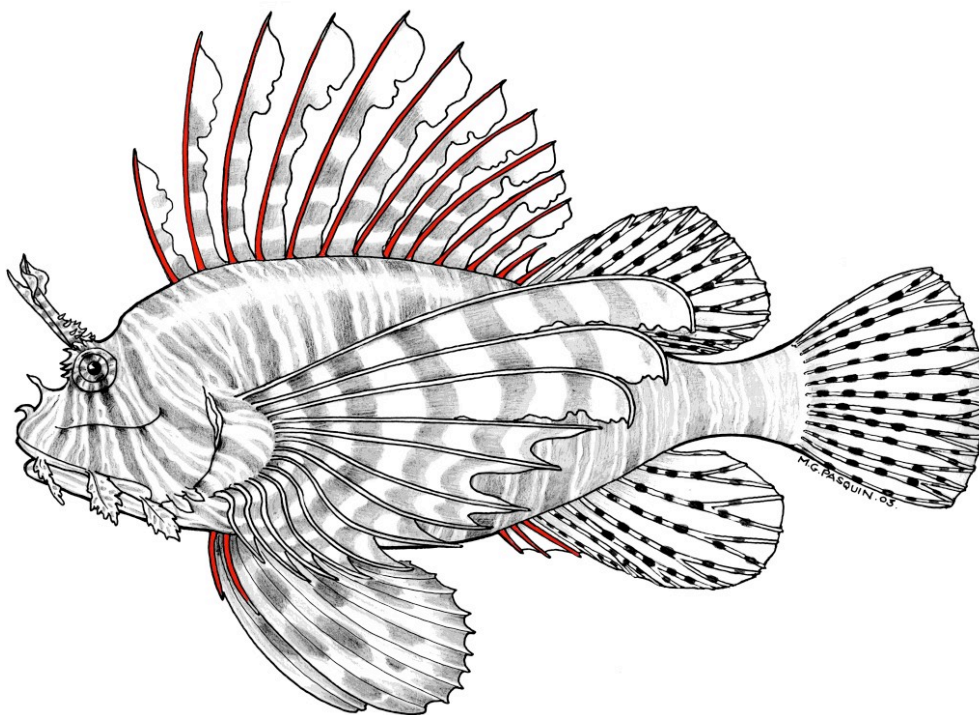
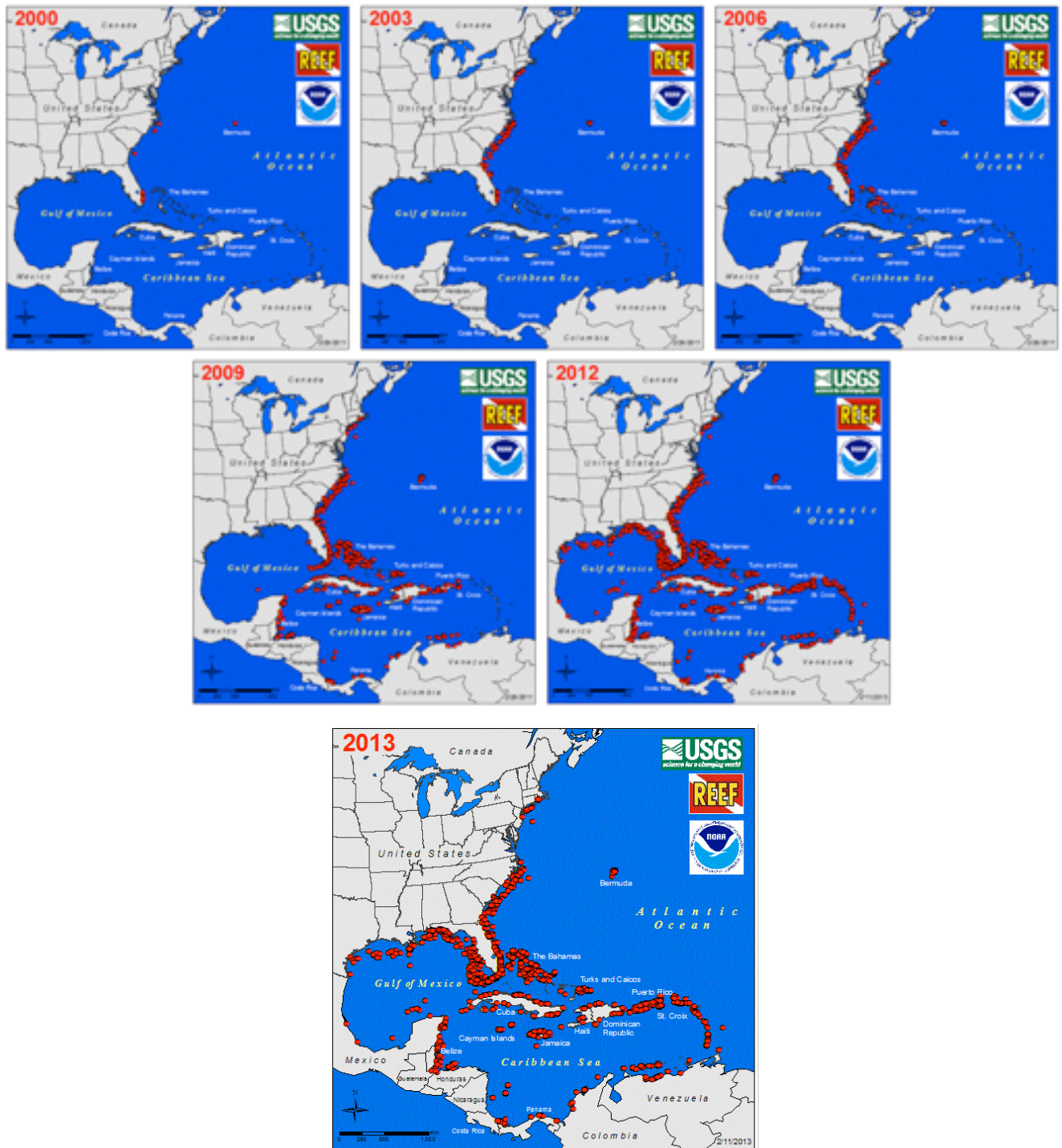


Illustration by Michelle G Pasquin

Current information suggests that in the temperate waters of the western Atlantic, lionfish reproduce approximately every 3 to 4 days, year round, with a single female capable of laying 2,000,000 eggs in one year. This data is supported by the dramatic growth and spread of the lionfish population throughout the southeastern Atlantic seaboard, Bermuda, the Caribbean, parts of the Gulf of Mexico and South America over the past decade. With no known predators, the lionfish population continues to grow unencumbered.



(Maps of spread of lionfish – 2000, 2003, 2006, 2009, 2012, 2013)





THE LIONFISH INVASION: *Past, Present, and Future* - James A. Morris, Jr

Taken from: *Invasive Lionfish: A guide to control and management*. 2012. Ed: J.A. Morris Jr.

The invasion of lionfish (*Pterois miles* and *P. volitans*) may prove to be one of the greatest threats of this century to warm temperate and tropical Atlantic reefs and associated habitats. As the first marine reef fish invasive species to this region, lionfish are changing the culture of how reef managers view invasive species, the regional connectivity of marine reefs, and their vulnerability to marine invasions.

The term “lionfish” is now as notorious as the other major invaders of the last century, such as Asian carp, kudzu, zebra mussels, and sea lamprey. Originally imported into the United States as a popular aquarium fish, the lionfish is now one of the most abundant top-level predators of many reefs. Lionfish pose a threat to the integrity of the reef food web and are capable of impacting commercial fisheries, tourism, and overall coral reef health.

Viewed in context with other reef stressors — such as land-based pollution, climate change, and overfishing — the lionfish invasion is distinguished by two obvious characteristics.

A RAPID, WIDESPREAD INVASION

The first outstanding characteristic of the lionfish invasion is that it has occurred rapidly across a wide geographic area. The initial confirmed lionfish sighting in the United States occurred in 1985, off Dania Beach, Florida. Some 15 years later, in 1999, the first lionfish sighting was made in Bermuda when one was found trapped within a tide pool. By 2000–2001, lionfish were identified as an established invader in the offshore waters of North Carolina, United States. At the time of this writing in 2012, lionfish are fully established throughout the Southeast United States, the Caribbean Sea, and much of the Gulf of Mexico. While lionfish have already reached the coast of Venezuela, they are expected to continue their invasion of the warm temperate reefs of South America, possibly reaching the border between Brazil and Uruguay.

BROAD DIET AND GENERAL HABITAT

The second pronounced characteristic of lionfish is their broad diet and general habitat preferences. Because of these factors, lionfish have the potential to affect the structure and function of many Atlantic marine communities — from the sea surface to depths exceeding 300 meters, and across habitats ranging from coral and hardbottom to artificial reefs, mangroves, and seagrass beds. For example, the high densities of lionfish observed in locations such as the Bahamas may be causing an abrupt change to the biodiversity and community structure of reef fish communities, and could constitute the most significant change since the beginning of industrialized fishing (Albins and Hixon 2011).



CASCADING IMPACTS

Alarming, lionfish may trigger cascading impacts through their disruption of the food web. For example, the lionfish consumption of herbivorous fishes could reduce the functional role of herbivores in keeping algae in check, a process known to be important for the health of coral reefs. Lionfish may also compete for resources — principally food and space — with economically important species, such as snappers (Lutjanids) and groupers (Epinephelids). It is uncertain if stock-rebuilding efforts will be able to return reef fish stocks to pre-lionfish abundance levels, especially those that are commercially harvested as well.

Lionfish could also affect the recovery of species of concern, such as the Nassau grouper (*Epinephelus striatus*), Warsaw grouper (*E. nigrilus*), and speckled hind (*E. drummondhayi*). These species are critically low in abundance and might not recover quickly under the additional predation mortality imposed by lionfish. [Note: In Bermuda, lionfish could also affect the status of Bermuda's black grouper (*Mycteroperca bonaci*), and the red hind (*Epinephelus guttatus*). The Nassau grouper are critically low in abundance in Bermuda and has not recovered from over-fishing. Any additional predation mortality imposed by lionfish will exacerbate the recovery process. Similarly, the black grouper and red hind could face additional pressure as lionfish could be predating their juveniles.]

Lastly, it is the interaction of the lionfish invasion with existing reef stressors that poses the greatest concern. Coral reefs of the Atlantic are already highly stressed from bleaching events, climate change, ocean acidification, overfishing, and pollution. The additional stress of this invasive species could accelerate and compound the degradation of coral reef ecosystem health in profound and unexpected ways.

LOCAL INTERVENTION IS CRITICAL

Local control efforts are critical for mitigating the effects of lionfish on key marine habitats. These efforts are invaluable for supporting other conservation initiatives, such as management of marine protected areas and fisheries stock rebuilding. The re-colonization of lionfish from remote and unmanaged habitats will continue to inflict constant stress on Atlantic marine communities. Until new technologies and approaches are developed for controlling lionfish populations, managers must be prepared for long-term intervention.



Section 4: Activities and Success Stories of 2013

INITIAL FUNDING TO COMMENCE RESEARCH

In early 2013, the Task Force initiated the submission of a Darwin Plus: Overseas Territories Environment and Climate Fund Project Application, to fund priority research components of the plan. In April 2013, this application was approved and the Task Force was awarded a grant of just under £170,000. This will go towards funding some of the major research components of the plan including:

- An initial lionfish population density and distribution study
- Development of a lionfish-specific trap for commercial fishers
- Researching information on feeding ecology to identify feeding rates and prey selectivity
- Investigation of reproduction dynamics (reproductive status and recruitment)

It is estimated that additional funding will be required as research work continues, but this represents an encouraging start.

SUCCESSFUL IMPLEMENTATION OF INITIATIVES

Members of the coalition have also implemented other important elements of the control plan:

- Implementation of the lionfish sighting and capture reporting programme, consisting of:
 - An online report form and printable versions of the report form (OSF website);
 - Six drop off sites, around the island, for forms and lionfish specimens, (BAMZ, BIOS Marine Resources Section/Coney Island and three dive shops, Triangle Diving, Dive Bermuda, and Blue Water Divers) and;
 - An online database to collect reports and specimen data for use by researchers (OSF website)
- Reinstatement of the lionfish culling permit programme and development of a tourist-related spearing programme. As of August 2013 over 280 individuals have received their culling permits. - (Marine Resources Section (DEP), OSF, Dive Bermuda with support from other member organizations)
- Presentations at the UKOT “Lionfish Response Strategy Workshops I & II”, in Anguilla, February 6th, 2013 and the Cayman Islands, July 1 and 2, 2013, sponsored by UK Joint Nature Conservation Committee (JNCC) - (Workshop I, Department of Conservation Services and Task Force Chair/OSF) – (Workshop II, Marine Resources Section (DEP))
- Gut content analysis research - (BAMZ, Corey Eddy - University of Massachusetts,



- School of Marine Science, Ph.D. Student)
- Parasite burden assessment - (Kayelyn Simmons, Nova Southeastern University, Master's student)
 - Education and outreach programmes for students and other audiences - (BIOS, OSF, BAMZ/BZS, BUEI, Groundswell, SPCA, BSAC). A few examples:
 - BUEI Lionfish Exhibit and Invasive Species Lecture Series
 - 2013 Groundswell Lionfish Tournament - *(64 lionfish speared, double from previous tournament)*
 - BAMZ Lionfish Exhibit
 - Student programs by BIOS, BAMZ, BUEI, SPCA, OSF
 - Website and social media materials
 - Lionfish documentary (Robert Zuill)
 - Development of a lionfish trapping experiment - (Marine Resources Section (DEP))
 - Deep water culling and searches for lionfish "Hot Spots" at depth - (OSF)
 - Shallow water culling (OSF, BIOS, dive shops, BSAC and individual members of the dive community)



Section 5. Control Plan Priorities

5.01. COORDINATION AND COMMUNICATION WITH AGENCIES AND GROUPS

A coalition of organizations established The Bermuda Lionfish Task Force as a means of coordinating the drafting of the Lionfish Control Plan. The Task Force has representatives from the major stakeholder categories and worked with groups of individuals from coalition organizations to draft the plan. Membership representatives on the Task Force will change as the implementation of the plan progresses to support the various stages of the plan.

The Task Force will coordinate the various components of the plan and act as the central point of communication between government, stakeholders, and the public.

Regular meetings of the Task Force will be held to review progress, recommend any necessary adjustments, and review the status of resources required for plan components. Subcommittees will be designated as required. Periodic reports may be submitted to the Task Force by coalition staff or volunteers conducting the various activities.



5.02. PRIORITY I: EDUCATION AND OUTREACH

No one person, organization, or group owns the lionfish problem. Therefore, as a community, education and outreach priorities are key for the generation of support to make the lionfish problem common knowledge and generate the interest of the local population to aid in control of these fish.

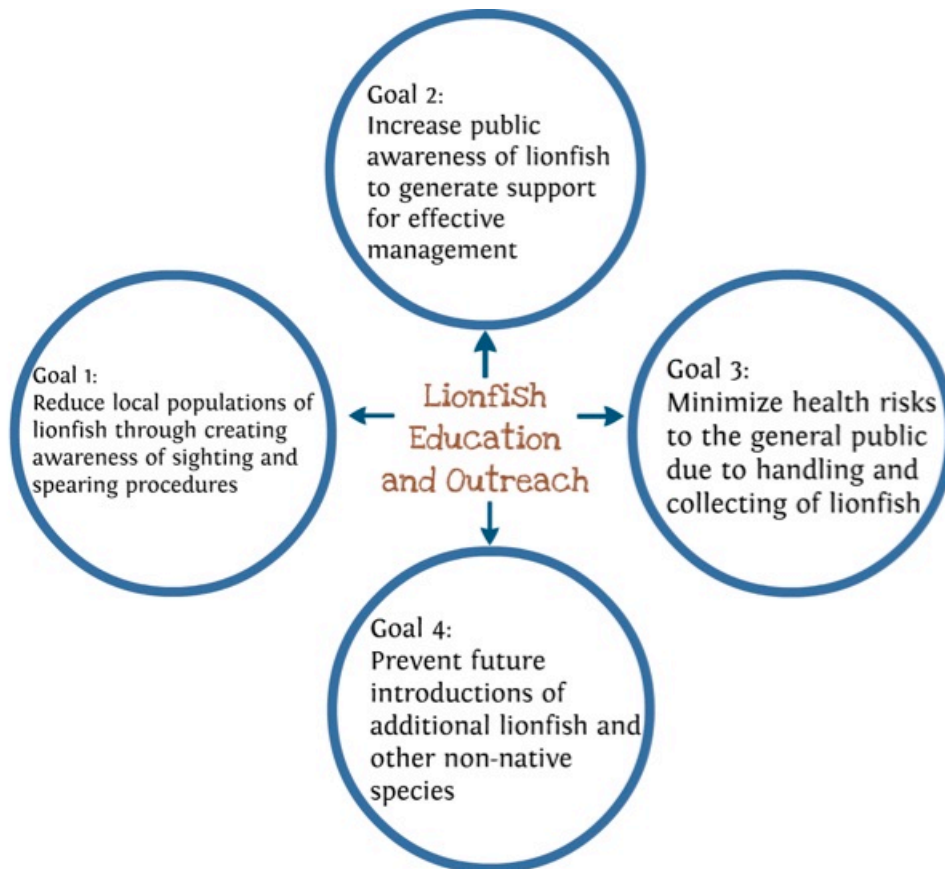


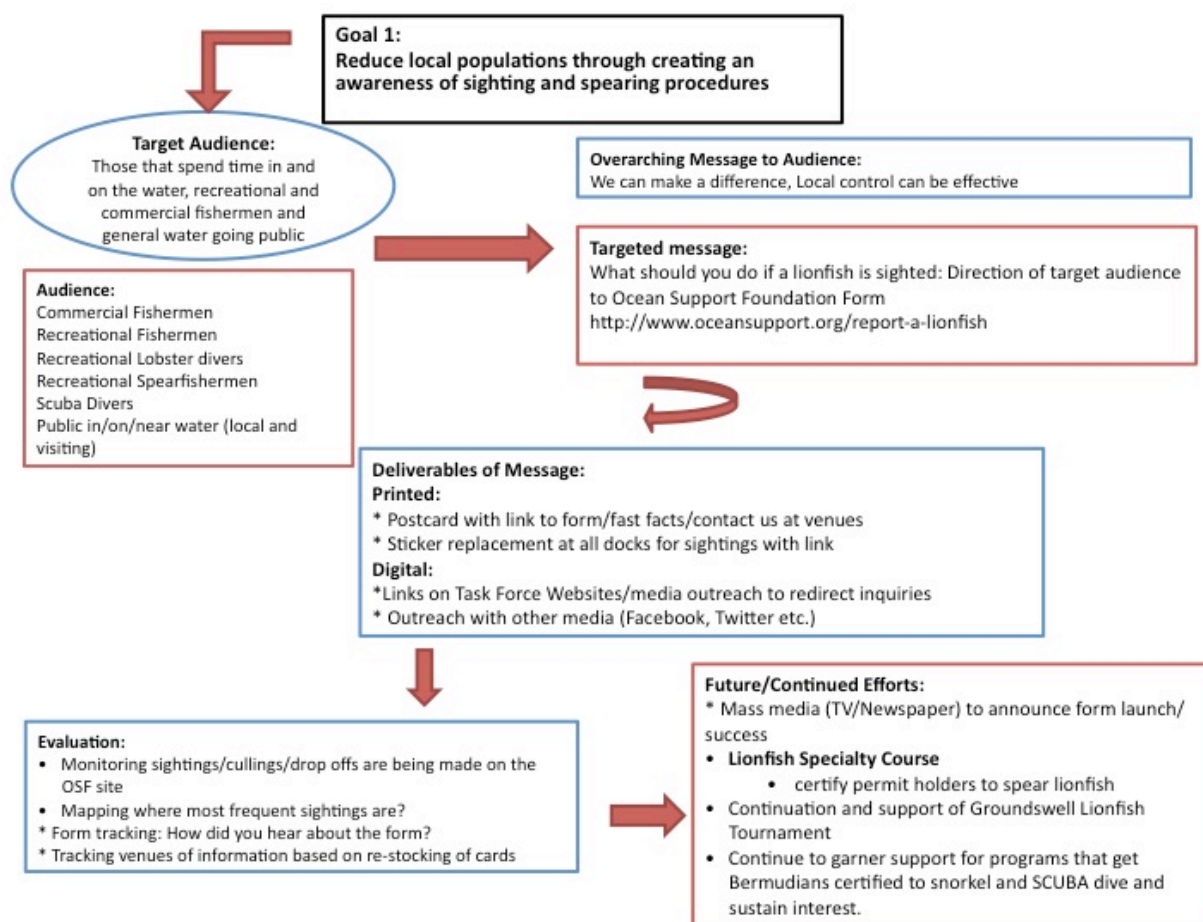
Figure 1: Four major goals of outreach and education with lionfish for the islands of Bermuda

Education and Outreach Goals

1. Reduce local populations through creating an awareness of sighting and spearing procedures – encourage people to report lionfish and to get trained to capture and consume lionfish – publicise the various reporting procedures including the OSF website reporting system
2. Increase public awareness of lionfish to generate support for effective management – stimulate people to demand action and to get involved in solving the problem



3. Minimise health risks to the general public on handling and collecting lionfish- reduce people's concerns about handling or consuming lionfish through demonstrations and media, e.g. videos, special events, publications
4. Prevent future introductions of additional lionfish and other non-native species. – work with aquarium trade and pet owners to understand the risk and impact of introductions



I. Goal One

Reduce local populations through creating an awareness of sighting and spearing procedures

A. Target Audience

Those that spend time in and on the water, recreational and commercial fishermen, and general sea- going public

Audience:

- Commercial fishermen



- Recreational fishermen
- Recreational spear fishermen
- Recreational lobster divers
- SCUBA divers
- Public in/on/near water (local and visiting)

B. Message

Overarching Message:

We can make a difference - Local control can be effective

Targeted Message:

What to do if a lionfish is sighted: Direction of target audience to Ocean Support Foundation Form

<http://www.oceansupport.org/report-a-lionfish>

C. Deliverables

Printed

1. Postcard with link to form/fast facts and a contact us at popular venues
 - Get the word out about what to do if a lionfish is spotted or captured.
2. Sticker replacement on waterways
 - Current signage on docks with telephone number is now null and void. Replace with appropriate information

Venues to put postcard with information:

- BIOS reception
 - BAMZ information Board,
 - In front of BAMZ Lionfish tank
 - BUEI information centre
 - Visitor Information Centre St. Georges
 - Cruise ship port information booths
 - Dive shops
 - Selected Shops and other public areas
3. Information within the Task Force display boards at BUEI exhibition

Digital



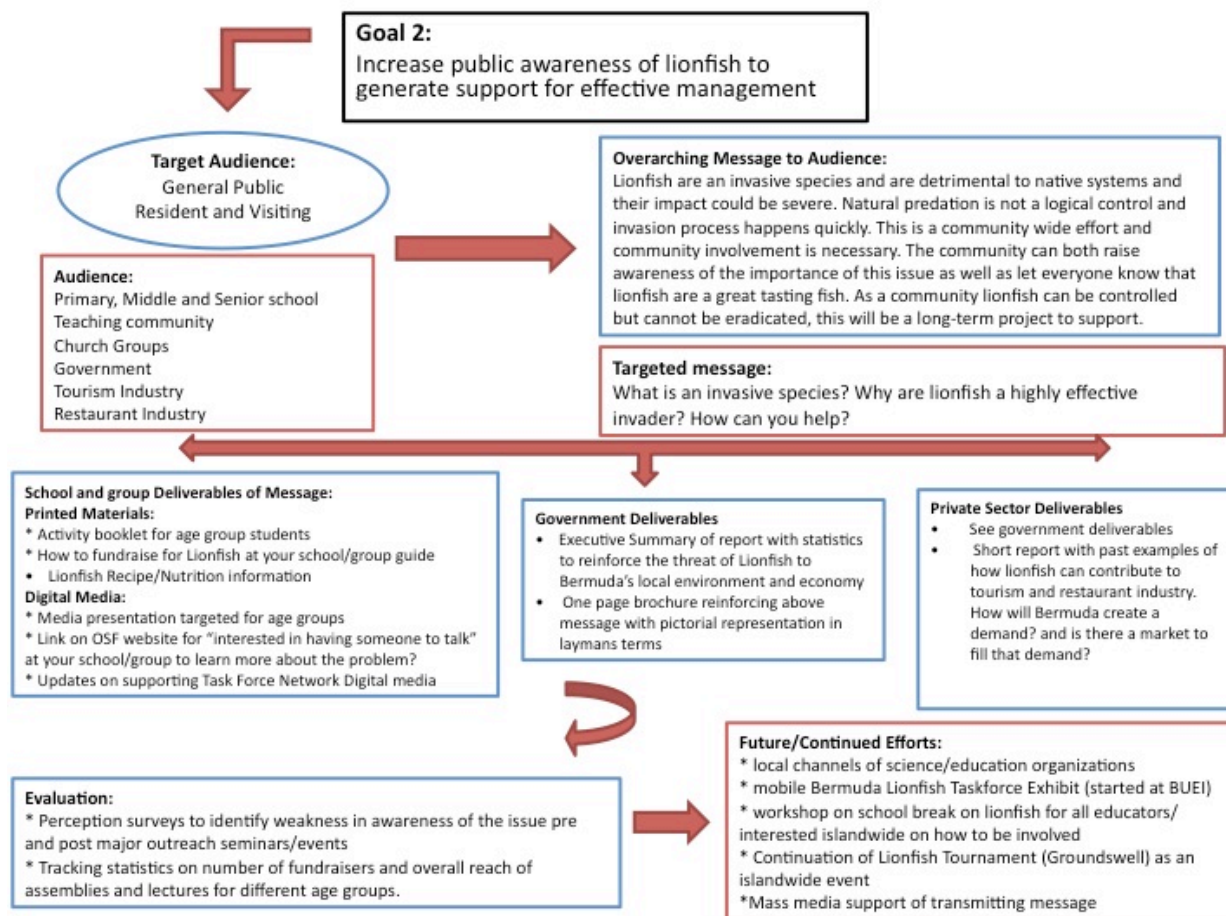
1. Link to form on Task Force Members websites to redirect inquiries
2. Media support with social networks to support the use of the form

D. Evaluation

1. Monitor sightings/cullings/drop offs that are being made.
2. Mapping where the most frequent sightings are.
3. Form tracking: how did you hear about the form?
4. Tracking popular venues for distribution based on re-stocking of cards

E. Future and Continued Efforts

1. Mass media (TV/newspaper to announce form launch/success
2. Lionfish Culling Permit Course
 - Certify permit holders to spear lionfish
 - Continuation and support of Groundswell Lionfish tournament
 - Continue to garner support for programmes that get Bermudians certified to SCUBA dive and programmes that support snorkelling activities that will sustain interest.



II. Goal Two

Increase public awareness of lionfish to generate support for effective management

A. Target Audience

- General public (resident and visiting)
- Primary, Middle and Senior school
- Teaching community
- Church groups
- Government
- Tourism Industry
- Restaurant Industry

B. Message

Overarching Message:

Lionfish are an invasive species and are detrimental to native systems and their impact could be severe. Natural predation is not an effective control and the invasion process happens quickly.



This is a community-wide effort and community involvement is necessary. The community can both raise awareness of the importance of this issue as well as let everyone know that lionfish are a great tasting fish. Lionfish can be controlled but cannot be eradicated, and this will be a long-term project to support.

Targeted message:

What is an invasive species? Why are lionfish a highly effective invader? How can you help?

C. Deliverables

School/School community

Printed

1. Activity booklet for age group students
2. How to fundraise for Lionfish at your school/group guide
3. Lionfish recipe/nutrition information

Digital

1. Media presentation for targeted age groups
2. Link on OSF website for “interested in having someone talk at your schools/group to learn more about the problem?”
3. Updates on supporting Task Force Network media

Government

1. Executive support of report with statistics to reinforce the threat of lionfish to Bermuda’s local environment and economy
2. One page brochure reinforcing above message with pictorial representation in layman’s terms

Private Sector

1. Executive support of report with statistics to reinforce the treat of lionfish to Bermuda’s local environment and economy
2. One page brochure reinforcing above message with pictorial representation in layman’s terms
3. Short report with past examples of how lionfish can contribute to tourism and restaurant industry. How will Bermuda create a demand? In addition, is there a market to fill that demand?

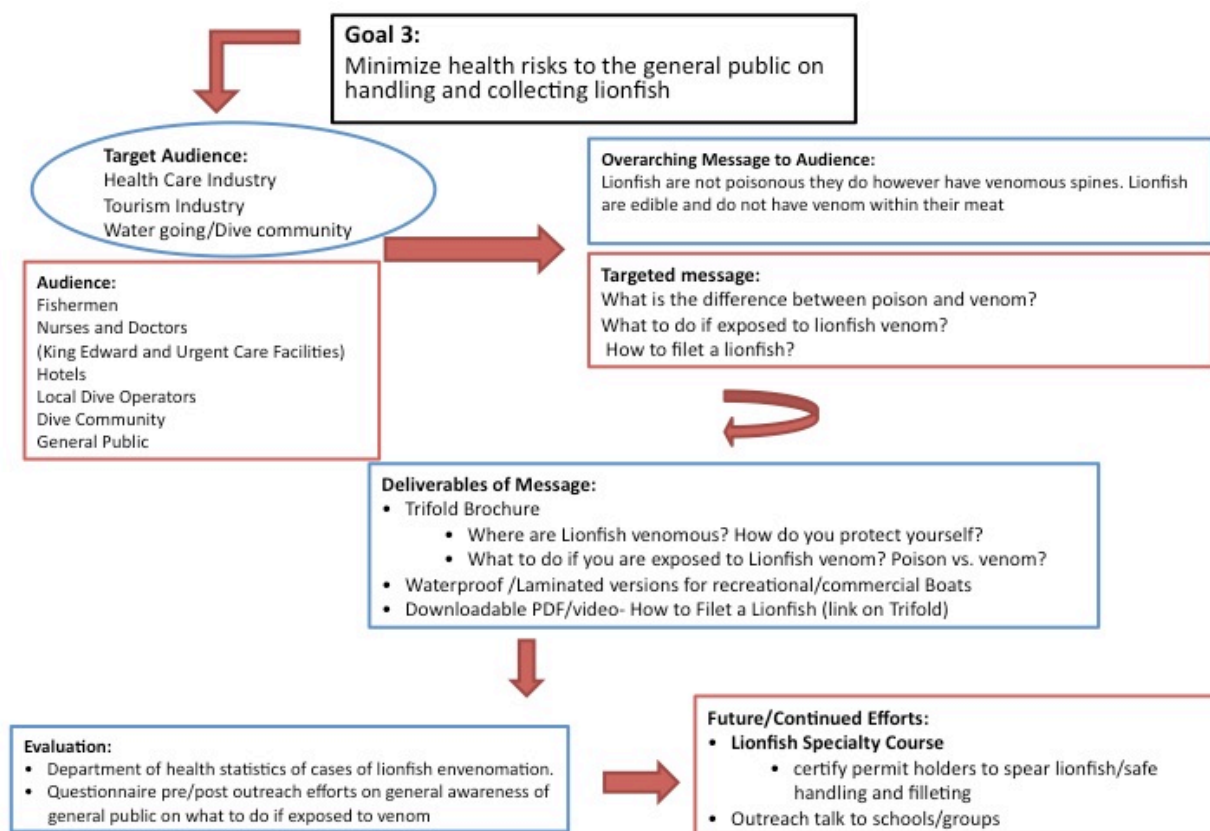
D. Evaluation



1. Perception surveys to identify weaknesses in awareness on the issue pre-post major outreach seminars/programmes
2. Tracking statistics on number of fundraisers and overall reach of assemblies and lectures for different age groups.

E. Future/Continued Efforts

1. Utilizing local channels of science/education organizations
2. Mobile Bermuda Lionfish Task Force Exhibit (starting at BUEI)
3. Participation in the invasive Species lecture series (at BUEI)
4. Continuation of Lionfish Tournament (Groundswell) as an island-wide event
5. Mass media support in supporting the message



III. Goal Three

Minimise health risks to the general public on the handling and collecting of lionfish



A. Target Audience

- Health Care Industry
- Tourism Industry
- Fishing Community
- Boating/Dive community

Audience:

- Nurses and Doctors
- Hotels
- Local Dive Operators
- Dive Community
- Fishermen
- General Public

B. Message

Overarching Message:

Lionfish are not poisonous they, do have venomous spines. Lionfish are edible and do not have venom within their meat.

Targeted Message:

What to do if exposed to lionfish venom. How to fillet a lionfish. What is the difference between poison and venom?

C. Deliverables

Printed Media

1. Tri-fold Brochure

- Where are Lionfish venomous? How do you protect yourself?
- What to do if exposed to Lionfish venom? Poison vs. venom?

2. Waterproof/Laminated versions for recreational/commercial boats

Digital Media

1. Downloadable PDF/video- How to fillet a Lionfish?
2. Lionfish Specialty Information (linked to OSF website)

D. Evaluation

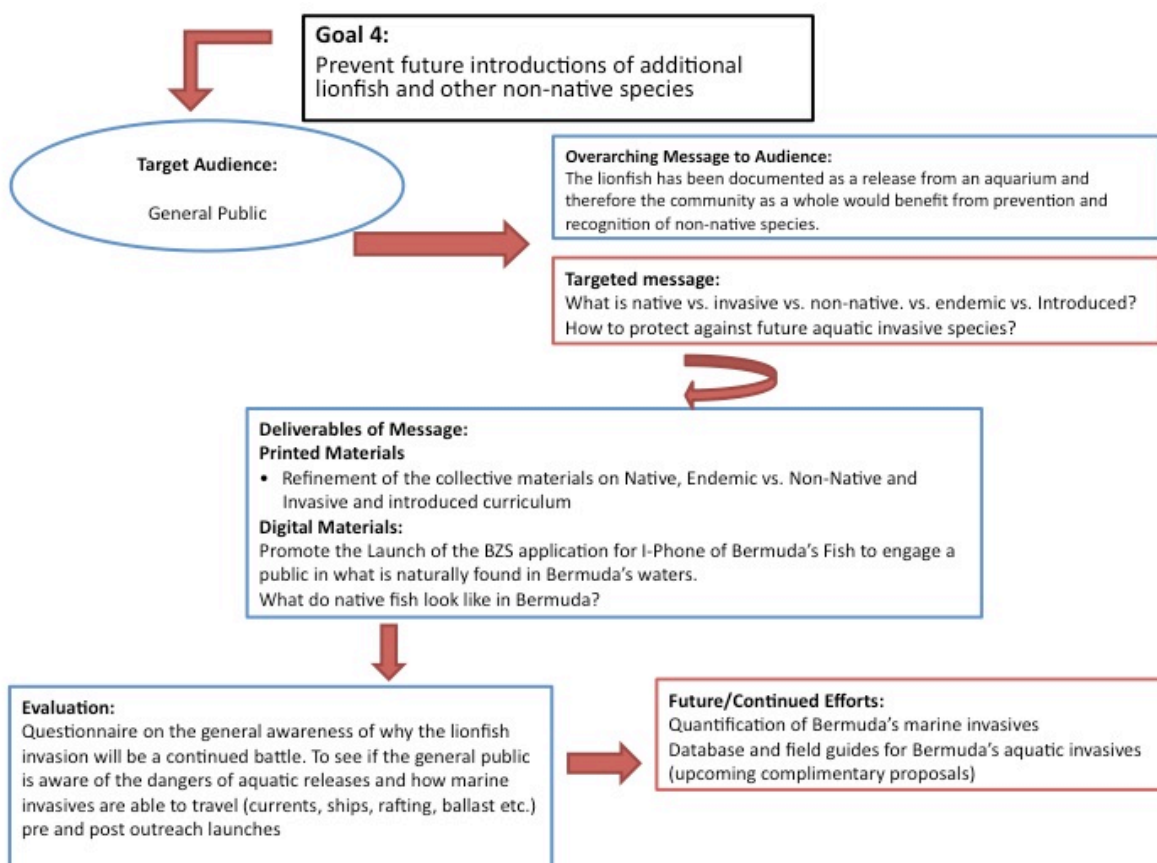
1. Department of Health statistics of cases of lionfish envenomation.



2. General awareness of general public on what to do if exposed via Questionnaire pre/post outreach efforts

E. Future and Continued Efforts

To be determined.



IV. Goal Four

Prevent future introductions of additional lionfish and other non-native species.

A. Target Audience

General Public

B. Message

Overarching message:



The lionfish has been documented as having been released from private aquaria and therefore the community as a whole would benefit from prevention and recognition of non-native species.

Targeted message:

What is endemic vs. native vs. non-native vs. invasive? How to protect against future aquatic invasive species?

C. Deliverables

Printed Media

- Local newspaper articles on the continuing battle against invasive species.
- Collation of curriculum on Native and Endemic vs. Non-Native and Invasive species

Digital Media

- Promote the Launch of the BZS application for I-Phone of Bermuda's Fish to engage the public in what is naturally found in Bermuda's waters.
- What do native fish in Bermuda look like?
- Link to OSF form as well as direction toward all deliverables of this document.

D. Evaluation

Questionnaire administered to public to see general awareness of why the lionfish invasion will be a continued battle. To determine if the general public is aware of the dangers of aquatic releases and how marine invasives are able to travel (currents, ships, rafting, ballast water, etc.)

E. Future and Continued Efforts

Quantification and catalogue of Bermuda's aquatic invasive species



5.03. PRIORITY II: RESEARCH AND ASSESSMENT

A major priority is the scientific assessment of the impact that the invasive lionfish may have on the local environment, in order to provide a strong evidence-based framework for the implementation of management strategies. It is essential to establish an accurate baseline for the lionfish population, including which habitats they colonise, what they eat, their capacity for reproduction, levels of recruitment and the current importance of different sources of new recruits to the population (self-seeded versus advection of larvae by Gulf Stream eddies). Information of this nature will provide insight toward the ultimate impact lionfish may have on the local environment..

i. Lionfish Population Density

Current sightings and reports indicate that lionfish are now well established across a wide geographic range, inhabiting offshore waters of the Caribbean, Southeast United States, and Bermuda. Sightings have been reported from all major benthic habitats within the invaded Atlantic, ranging from the shoreline up to 300m (1000ft) depth, including mangroves, estuaries, seagrass-beds, and coral reefs. Densities from these reports indicate that lionfish are far more abundant in their invaded range than throughout their natural territories in the Indo-Pacific region. Reported average densities presently range from approximately 150 fish per hectare off North Carolina (Morris and Whitfield 2009) to 393 fish per hectare in parts of the Bahamas (Green and Côte 2009). This is in stark contrast to the findings of Kulbicki et al. (2012) who report 26 fish per hectare of *Pterois* species across their native Indo-Pacific region. Locally, there have been no quantitative assessments of lionfish densities. In the spring of 2013 a Darwin Plus grant was received that will cover this issue along with other areas of lionfish research.

Until recently, anecdotal evidence suggested that lionfish are more commonly found in water greater than 20m deep in Bermuda, however, increased reports were received in 2013 of lionfish sightings in shallower waters. Lionfish abundance in Bermuda will, therefore, be assessed across all accessible depth zones using diver surveys at sites dispersed amongst five depth intervals (e.g. 0-10m (0-30ft), 11-20m (30-60ft), 21-30m (60-100ft), 31-45m (100-150ft), > 46m (>150ft). These sites will include critical habitats such as fish spawning aggregation sites (e.g. black grouper, hind, and grunts), and nursery habitats such as mangrove forests and seagrass beds (Biggs and Olden, 2011; Clayden et al., 2012). A subsection of sites, including those frequently visited by the diving community, will be revisited at intervals to evaluate re-colonization rates, seasonal changes in abundance, and the success of culling/removal efforts. Based on the recommendations in Green, 2012, surveys will also include estimates of fish length and information on depth, seawater temperature, interesting behaviours, habitat complexity, site location (with GPS coordinates), and environmental conditions. Lionfish will be captured concurrently for later assessment of reproductive status, gut analysis, and genetic analysis.



Likely collection methods include paralyzer-tipped pole spears, dip-nets, or suction guns. Furthermore, lionfish captured locally by commercial lobstermen will be collected and examined, as the opportunities arise.

ii. Feeding Ecology

Analysis of stomach contents and stable isotopes indicate that lionfish are opportunistic generalist carnivores (Munoz et al., 2012) with a diverse diet that includes various fishes and crustaceans, which may be consumed in relation to their local abundance. The feeding habits of Bermuda's lionfish population are not well known, although preliminary evidence supports the pattern of generalist, opportunistic predation. One lionfish was captured at 75 ft (23m) and was estimated to have over 34 juvenile barbers (*Paranthias furcifer*) in its stomach.



It is anticipated that stomach contents and stable isotope analyses of the lionfish tissues will be performed on the majority of captured specimens to accurately determine the feeding ecology of Bermuda's lionfish. Stomach contents will be identified to the lowest possible taxonomic level, whilst samples of muscle, liver, and fin tissue will be collected for analysis of stable isotopes. This analysis is a novel approach that provides insight toward the lionfish's trophic position, the foundation of its food web (i.e. inshore versus offshore), as well as potential diet shifts related to growth, seasonal change, or migration. Representative samples of prey fish tissue stable isotope ratios will be collected to relate to the lionfish diet choices and lionfish tissue stable isotope ratios.

The gut contents data will be compared to those generated by the prey reef fish surveys described below. Any emerging prey preference patterns will indicate which prey species are more vulnerable to the presence of lionfish. Furthermore, correlations between prey abundance and predation may provide an indication of factors affecting the overall distribution of lionfish, specifically resource availability or preference.



1. Demographics and Recruitment

While it is important to know the size of Bermuda's lionfish population, we must also understand the demographic trends of the population. Common demographic parameters are gender, length, weight, reproductive status, recruitment rate and age. It is important to evaluate these patterns as fish of different developmental stages may have differing effects on reef fish communities. A recent study by Albins (2012) suggests juvenile lionfish are not ecologically equivalent to native piscivores but had stronger effects on local reef fish assemblages. Recruitment patterns are a key element in demographic studies. We need to know the rate of recruitment and the sources of new recruits to the population. In many locations, lionfish are able to spawn regularly throughout the year, but it is not yet clear whether this occurs in Bermuda. In addition, Bermuda receives recruits from other parts of the Northwest Atlantic. It is important to know the extent to which the population is self-sustaining versus supplied by larvae arriving from elsewhere via the Gulf Stream, as this will influence the effectiveness of local control measures and the frequency with which they must be carried out.

With these questions in mind, we will conduct various investigations using tissue samples, otoliths (i.e. fish ear bones) and reproductive organs. Otoliths have growth increments similar to the rings of a tree trunk; these can be counted to determine the age of fish and the timing of recruitment. These data will provide information on the age structure of the lionfish population and an estimate of life expectancy, derived from a growth curve. Similarly, an examination of the gonads will tell us the gender and maturity of each fish, allowing us to estimate sex ratios, seasonality of reproduction and the potential reproductive capacity of the local population. We will compare the genetic characteristics of local lionfish with those captured in other parts of the Atlantic using highly variable microsatellite markers to determine the source of lionfish recruits, (local vs. foreign) and the rate at which they are arriving in our waters. Lionfish larvae will be collected using light-traps.

iv. Assessment of Fish Communities

The presence of lionfish on Bermuda's reefs represents a potential challenge to the populations of reef fishes because of prey naiveté and the aggressive consumption of prey by the lionfish. The juvenile stages of many reef fishes are most vulnerable and thus the overconsumption by lionfish could limit some fish populations. Bermuda has depressed populations of many native predators (groupers, snappers, etc.) as a result of decades of over-fishing that targeted these species. Therefore, it is unclear whether lionfish will have a further depressive effect on local fish populations compared to historic times. But the substantial impact lionfish have had on reef systems in the Caribbean is clear and thus it is essential that a monitoring programme is established to quantify reef fish populations on Bermuda's reefs in order to form a contemporary baseline to assess the effectiveness of lionfish control efforts in limiting their impact on native reef fishes.



There are several significant studies on the abundance of fishes on Bermuda's reef. The most recent were synoptic surveys by Murdoch et al (2008, and in prep.) within Marine Protected Areas and at sites at 10m, 20m, and 30m depths across the lagoon, the rim reef, the reef terrace, and upper fore-reef slope. Murdoch et al (2008) employed a modified visual AGRRA *in situ* survey technique. Historic large-scale visual surveys were done by Luckhurst (1994) and the Marine Environmental Program at BIOS (2005); but were generally limited to rim reefs and lagoon patch reefs. Smith and Pitt (2002) and Smith et al. (2003) reported on the distribution of juvenile fishes on shallow reefs around Bermuda using a visual survey method.

There is a paucity of data on reef fish populations below 20m depth and these are the depths where lionfish seem to be aggregated (Maddocks per comm., OSF). The great challenge is the limitations on dive time at depths below 30m that would facilitate *in situ* fish censusing. The lack of data will limit our understanding of the current level of impact the lionfish have already imposed on these deep reefs over the past decade.

It is recommended that prey fish, as well as the fish community as a whole, be studied at replicate sites in each reef zone, taking into account the broad depth range over which lionfish have been observed. These sites should, where possible, include sites used in earlier studies in order to develop a perspective of change over time. Different methods may be required for gathering data over the full range of depths to be studied, but any methods used should aim to produce comparable results.

Underwater visual census is the most effective means of studying fish communities in shallow reef zones where dive times are sufficient to allow it. The small size and patchy distribution of potential prey fish require replicate intensive surveys on 2m x 30m transects with a diver recording all fish smaller than 12cm in length. It is recommended that the modified AGRRA survey technique of Murdoch et al (2008 and in prep) be used to study the fish community as a whole, since the Murdoch data are the most recent and comprehensive, and form the broadest baseline on reef fish communities to date. However, these methods are limited by available dive time and the number of trained observers that are certified to dive beyond recreational diving limits.

Since trained fish observers and dive time are both limiting factors on dives below 30 m, video-based survey methods may be used to assess fish communities at replicate sites at different depths between 30m and 60m on the deep fore-reef. Various options for video data collection exist, including video transects conducted by technical divers, a stationary video camera placed by a diver, stationary video from a weighted mooring, or video transects from a drop camera operated from a drifting vessel. The method(s) chosen will depend on the resources and personnel available, but should be calibrated to ensure that the data produced are consistent with other surveys.



It is recommended that the data analyses at each site include:

- Species-specific patterns of abundance per m² over time at each site
- Size class distributions of each species and tests for changes in the distribution over time at each site.
- Functional guild (planktivores, herbivores, predators) patterns of abundance and changes over time at each depth.
- Comparison of zonal patterns of abundance (within and between zones) for key species, especially vulnerable prey species targeted by lionfish.



5.04. Priority III: DETECTION AND REMOVAL (Control Mechanisms)

i. Shallow water culling

Building on the initial lionfish-culling programme that started in 2008, interested local volunteers will be trained to cull lionfish at depths accessible to snorkelers and recreational divers. Cullers will be trained in appropriate spearing and handling techniques and informed of permit requirements via workshops held by OSF on behalf of the DEP and the Bermuda Lionfish Task Force, with the help of other Task Force organizations. Upcoming courses will be publicised on Task Force partner websites, local newspapers, and other media.

Once training has been completed, cullers will be issued permits on an annually renewable basis through the DEP's special permit system, under which activities that do not comply with the Fisheries Regulations 2010 must be conducted. While there is nothing to prevent regularly licensed spearfishers from spearing any lionfish that they might encounter, a permit is required for cullers to use a spear while using a SCUBA tank and/or to use a spear within 1 nautical mile of the shore. This permit would also allow anyone who does not otherwise spearfish to use a spear to cull lionfish without the need to obtain a spearfishing license.

As a lionfish-culling permit provides opportunities for circumventing the Fisheries Regulations, permitted cullers will have to abide by strict protocols to minimise the risk of violations. Lionfish culling spears may not be longer than 5', and all cullers will be required to report on their culling activities and upload data on their catches to the OSF database.

Culling permits will generally be issued to individuals, but certain partner organisations whose members spend a lot of time in the water will be issued a group permit. Examples of organisations for which group permits could be issued include the various dive shops, BIOS, and other marine tourism operators.

Dive shops are also exploring ways in which visitors to Bermuda may get involved in lionfish culling through a dedicated specialty course.

The removal of juvenile lionfish is particularly important for a control programme to be effective, and specially trained divers culling with small spears provide the greatest chance of success for capturing small individuals. However, fish of this size are difficult to observe and their presence in Bermuda has been recorded so infrequently that there is little information from which to develop a removal protocol. Ongoing collection of survey data aims to gather this information and protocols will be developed when more data is available.

Dive shops and individual divers will be encouraged to adopt a section of reef and visit it regularly to search out and cull any lionfish that might be present. Intention to adopt a reef area should be registered with the Task force/OSF to avoid duplication of effort.



Cullers will also be encouraged to volunteer to be part of the Lionfish Sighting Response Team that will go out specifically to search for lionfish reported by members of the public who were not in a position to capture them. The response team management will be co-coordinated through the DEP along with the OSF website and the dive community. This process is being discussed as of this writing.

ii. Deep water culling

The need for deep water culling should not lead to compromises on appropriate dive safety requirements. Volunteers trained in appropriate deep diving techniques will conduct deep water culling activities under the auspices of the Ocean Support Foundation following strict dive protocols. Deep water culling by divers should focus on marine protected areas that are closed to fishing, where a lionfish trap fishery would not be able to operate. However, until a functioning trap fishery is developed, culling by divers represents the most effective means of removal from aggregated populations at depth, and thus deep water culling by divers should occur across the Bermuda platform and be a main focus for control efforts. Further evaluation of deep-water technology is underway and will take time and money to determine if there are better ways of exploiting the large aggregations of lionfish that may be found at depth. Collaborative projects with other UKOTs and Caribbean countries should be explored.

iii. Lionfish and the Commercial Fishery

Lionfish have been caught as by-catch in Bermuda's commercial lobster trap fishery since at least 2003, and have been a regular feature since 2008. In 2010, the Department of Environmental Protection released a 15-year Strategic Plan that included developing a commercial fishery for lionfish, as a way of combating the invasion and also providing a new target for the local commercial fishery. A brief experiment was conducted with three traps with various modifications and the assistance of Ocean Support Foundation divers as observers, but the protocols proved too time-consuming and few trap sets were completed.

A pilot project has now been designed that will include existing commercial lobster fishermen from each end of the island. The goal is to develop modifications to the existing traps and deployment protocols used by the commercial lobster fishery to increase the catch of lionfish, reduce the catch of spiny lobster, and maintain the low levels of finfish by-catch for which this standardised trap was developed. Self-contained underwater video equipment to monitor the effectiveness of the experimental traps will be employed as well. It is expected that this pilot project will begin some time in 2013.

It is anticipated that a lionfish trap fishery would be operated in conjunction with the offshore lobster fishery, for at least the months of September through December. Weather conditions in January through March make it impractical to operate at these depths and distances from shore during the latter part of the lobster season. If lobster by-catch can be sufficiently reduced, the



lionfish trap fishery could potentially operate during the summer months as well, but the need to protect brooding female lobsters must take priority over expanding the lionfish-trapping season if lobster by-catch remains an insurmountable issue.

At present, it is anticipated that lionfish trapping would only take place on the edges of the Bermuda platform. Lionfish are known to be present on the offshore banks (Challenger and Argus), however the paucity of visual observations at these depths means that their abundance and the abundance of their prey is unknown. The potential impacts of lionfish on the offshore bank ecosystem are therefore unknown, and the information needed to determine whether removal activities could be effective or should be prioritised will be difficult and costly to acquire. In the future, once the platform control programme is well established, some resources could be diverted to assessing the prevalence and impact of lionfish on the offshore banks, as a large population there would likely contribute many recruits to the platform itself.

The depths of Argus and Challenger banks mean that trapping is the only removal mechanism that could be employed to regularly capture lionfish in this habitat, but there are several factors that contribute to the difficulty of implementing a trap fishery there. At present, the commercial lobster fishery is not permitted to operate on the banks, so lionfish traps would have to be operated on their own in these areas. The travel time and associated fuel consumption to reach the banks would increase the relative cost of lionfish trapping there, possibly beyond the point at which it would be economically viable for commercial fishermen. In addition, any animals brought to the surface from these depths would likely not survive, so by-catch reduction would have to be extremely effective for lionfish trapping on the banks to be considered. However, if these issues can be overcome and suitable controls can be put in place, it is possible that the lionfish trap fishery (or some sort of alternative trapping programme) could be expanded to include the banks.

iv. Criteria and Processes to Prioritise Areas and Resources

Developing a map of the distribution and relative abundances of lionfish around the Bermuda platform is one of the objectives of the planned baseline surveys. This map will be used to identify 'hotspots' where lionfish control activities will be focused. Areas with the greatest densities of lionfish will be prioritised for removal activities using the method most appropriate for their depth, as this will be the most efficient way to facilitate removal of the greatest number of individuals.

Important recruitment habitats must be included in baseline and follow-up lionfish surveys. If any lionfish are found in recruitment habitat, those sites will be prioritised for removal activities regardless of the density of lionfish observed, as reduction of lionfish impacts in such areas is critical for juvenile fish survivorship. The same must also apply to marine protected areas (MPAs) in order to maintain the integrity of the ecosystem in these key marine management



areas. Removal of lionfish from recruitment habitat and MPAs will be the primary focus for permitted cullers. Trapping is not an appropriate removal method for either recruitment habitat or MPAs because of the risk of habitat damage, and fishing boats are prohibited from operating in MPAs in any case. The commercial dive boats frequently visit MPAs, and this is a practical way to focus their culling efforts in areas that will benefit from regular lionfish removals. Other permitted cullers should be encouraged to include recruitment habitats, once they are identified, in their efforts. Culling visits to recruitment habitats may also provide opportunities to search for juvenile lionfish. Additional training may be offered to those interested in specialising in this area, perhaps in association with the Ocean Support Foundation and Task Force partners.

The risk that lionfish present to public health means that popular swimming areas should also be regularly checked for lionfish and prioritised for removal activities. Based on what is known about thermal tolerances of lionfish, it is expected that lionfish are only likely to be present in shallower waters during the warmer months. However, this is precisely the time period during which beaches are mostly heavily used. A survey of swimming beaches early in the summer, combined with good outreach protocols to promote prompt and effective reporting of lionfish sightings by members of the public, will help prioritise removal efforts focused on swimming areas. At beaches with lifeguard supervision, collaboration with the Parks Department to train the lifeguards to cull lionfish might be the most effective way of responding to sightings. (This may only be feasible if lifeguards cull voluntarily on their off hours.) Appropriate culling equipment, including mask / snorkel, spear, gloves and cooler with ice could be kept on hand at the lifeguard stations. This approach will need to be discussed with the Parks Department. Otherwise / In addition, removing lionfish from swimming beaches will be the highest priority for the Lionfish Sighting Response Team that will be formed from amongst the permitted cullers.

v. Removal Incentives

Because of the nature of the lionfish invasion, long-term removal programmes will be required. Keeping people and organizations incentivised will be critical task. Monetary incentive beyond a commercial fishery will need to be explored, centring on recognition oriented incentives. This area has not been adequately addressed at this time but it is recognised that a long-term programme will have to be developed.



5.05. PRIORITY IV: MONITORING AND DATA GATHERING

i. Monitoring Local Lionfish Populations

Long-term monitoring of the lionfish population is an essential element to any control plan. It provides a method to examine changes in lionfish population size and demographics, their rate of re-colonization, and the effectiveness of removal/culling efforts. This allows managers to evaluate whether the control strategy is achieving its goals and will provide directions on how actions can be improved whilst providing details on the effort required to effectively control the invasion. Similarly, long-term monitoring of reef fish populations will inform us of the impact lionfish are causing on prey fish populations and subsequent ecological changes. The key questions that must be addressed in any monitoring programme are:

- Is lionfish abundance/density changing over time?
- Are certain locations invaded more rapidly than others?
- Are removal efforts effective?
- How much effort is required to control the population?

Successful lionfish control programmes should involve monitoring by the public, trained volunteers, and resource managers/researchers. With minimal training, members of the public can collect and report lionfish sightings during recreational activities, increasing the number of opportunistic sightings. Additionally, volunteers who receive standardised training in collection protocols can participate in monitoring efforts using SCUBA or snorkel. Bermuda is fortunate that it has a lobster trap fishery. Anecdotal evidence suggests lionfish are frequently caught in lobster traps, often in large numbers. Considering these traps are often set at the depths beyond recreational limits and widely dispersed across the island's reef environment, the spatial information derived from lobster traps is an absolute bounty. Finally, specially trained resource managers and volunteers can generate high-resolution data on the spatial and temporal distribution of lionfish. Although monitoring by trained individuals is resource-intensive, it yields the highest-quality data.

Lionfish are cryptic in coloration and behaviour and patchily distributed on the reef, thus the probability of detecting them using standard survey protocols is low. Therefore, a thorough lionfish-focused survey is suggested for trained resource manager and researchers. The observer swims in an S-shape pattern with a recommended search rate of 10 m² per minute along a 25 m x 10 m (length x width) transect, taking special care to look under all overhangs, in crevices, and in cracks. During each survey, the total number and size (total length) of all lionfish are recorded; the minimum search time for each transect is 25 minutes.

Locally, the Ocean Support Foundation, with support from various stakeholders and sanctioned by the DEP, have developed a Lionfish Culling Programme and an online reporting system (www.oceansupport.org). Local residents over the age of 16 years can receive an annual lionfish



culling permit after being introduced to the basic biology and ecology of lionfish, their potential impact upon our reefs, capture methods and permitting requirements. Furthermore, the local dive operations have committed to culling and removal of lionfish found at sites they frequent. Similar to the fishing community, these stakeholders provide valuable data on re-colonisation, culling/removal success rates, and habitat preferences. By frequenting specific dive sites, the operators help promote the idea of adopting a reef, thus giving the community the feel-good factor through ownership.

ii. Monitoring Native Species

The baseline fish community assessment study will provide detailed site and depth-specific patterns of abundance of fish species that could be directly or indirectly affected by lionfish. Key species will be determined that appear to be vulnerable to the effects of lionfish predation or displacement via lionfish presence at specific locations. The monitoring programme will track long-term changes in both lionfish populations and impacted species to determine the effectiveness of the lionfish control programmes.

It is recommended that monitoring efforts include replicate sites in each reef zone used in the baseline assessment, preferably re-surveying some of the same sites. The surveys should be conducted at 3-year intervals, preferably at the same time of year as the baseline assessment. The Monitoring programme would use the same survey methods employed in the initial fish community assessment.

It is recommended that the following analyses be performed and incorporate the data from the baseline surveys:

- Species-specific patterns of abundance per m² over time at each site,
- Size class distributions of each species and tests for changes in the distribution over time at each site.
- Functional guild (planktivores, herbivores, predators) patterns of abundance and changes over time at each site.
- Comparison of zonal patterns of abundance (within and between zones) for key species, especially vulnerable prey species targeted by lionfish

The persistent absence of lionfish from a specific reef zone over a 3-year period would indicate success in their control and remove the need to continue to study the fish populations in that zone on a regular basis.

iii. Monitoring Ecological Impacts

The impact of lionfish on resident reef fish populations has the potential to alter key feeding relationships on coral reefs by reducing the populations of key fish species. The reduction or loss of key herbivorous fishes (such as damselfishes, parrotfishes and surgeonfishes) on coral



reefs can significantly alter the control of reef algae, via their grazing. Diminished herbivory can allow reef algae to gain a competitive advantage over slow-growing corals, resulting in the loss of coral cover.

It is recommended that replicate AGRRA reef survey transects (Murdoch, 2008) be conducted in conjunction with the fish community monitoring. The transects will measure coral and algal coverage and provide an index of reef health that is related to resident reef fish populations. This method does rely on a surveyor to be able to identify all common and rare reef species (corals, sponges, algae etc.) accurately in the field and this requires extensive training to accomplish.

An alternative is to use a video transect survey method (Aronson et al 1994; Murdoch and Aronson, 1999) that relies on a diver-operated video camera recording the reef surface from a fixed distance off the bottom (usually 40-50 cm). This method has been widely used on Bermuda's shallow reefs (MEP, 2007). The video is reviewed on a computer to identify and assess the relative abundance of organisms or substrate types as a measure of the reef community. This method has significant statistical power to detect changes in the reef community (Aronson et al 1994) and will facilitate the study of the deep fore-reef community within dive time restrictions. The advantages of the video transects are the creation of permanent records of the sites and the ability to provide quality control on species identification. The drawback of the method is that it is time-consuming to process the video data.

Additional work will be required to fully develop this section of the plan.

iv. Organismal Monitoring Through Dissection

The Lionfish Control Plan aims to cull significant numbers of lionfish with traps and spears. In order to determine the significance of the impacts of the lionfish on resident reef fishes it will be important to conduct gut analyses of the culled fish to determine their prey preferences and how prey choices match the availability of the fishes on the reefs.

It is recommended that the gut analyses should be performed on at least 50 lionfish from each of the four reef zones. Lionfish in a range of sizes should be examined from each zone. Efforts should be made to coordinate spearing and trapping to coincide with the fish community surveys in early summer. Gut analyses could be done at other times of the year or on sporadically collected fish.

The gut analyses will follow the methods of Morris and Akins (2009) and will consist of measuring the displacement volume of all prey found in a gut. The individual gut items will be identified to the lowest taxonomic levels and the total length of all prey fishes measured, if possible. The contribution of each prey taxon to the overall diet will be assessed using the following three relative measures of prey quantity: percent frequency of occurrence (%F), percent composition by number (%N), and percent composition by volume (%V).



The relative abundance of prey species in the guts of lionfish at specific study sites will be compared to the fish community data to assess availability of prey to the lionfish and their capacity to significantly impact these species. Any trends in the reduction of preferred prey fishes at sites with lionfish will be judged as negatively affected by the lionfish consumption. Stability in prey fishes over time would indicate that the lionfish have not been effective in controlling these fish populations.

v. Monitoring Socioeconomic Impacts: Fisheries, Tourism and Human Health

In addition to monitoring the ecological impacts of the lionfish invasion in Bermuda, it will also be important to monitor the socioeconomic impacts on fisheries, tourism, and human health. Both tourism and fisheries can be impacted by the ecological impacts of lionfish, i.e. by a negative change in the health of the reef ecosystem.

A decline in reef health is likely to have a negative effect on the experiences of tourists who come to the Island to snorkel, SCUBA dive, fish or otherwise interact with marine life. It is also likely to coincide with a decline in the catches of commercially and recreationally important fish species, which will adversely affect fisheries. The risk to human health is also a concern as an increase in the abundance of lionfish could increase the probability of tourists, fishermen, and residents encountering a lionfish and being stung by one.

Monitoring Fisheries

The lionfish affects fisheries by decreasing the catch per unit effort of the target species. This occurs mainly in two ways: 1) lionfish may affect the population size of the target species through predation and/or competition, and 2) lionfish may interfere with fishing activities so that the cost of fishing increases with regard to time, effort and/or safety risk.

The Marine Resources Section of the DEP monitors fisheries in Bermuda. Currently, the fishery in which the largest numbers of lionfish are being captured in Bermuda is the spiny lobster (*Panulirus argus*) trap fishery. This is also the fishery from which the most detailed data is collected.

Monitoring indicators for the fishery will be:

- Catch-per-unit-effort (CPUE) and total catch of spiny lobster
- By-catch-per-unit-effort and total by-catch of lionfish

The Marine Resources Section will collect the following information from the fishery:

- Location and depth of fishing (habitat will be determined from this information)
- Total number of traps fished
- Total number of spiny lobsters caught
- Total number of lionfish caught



- Measurements for at least 10% of the captured lobsters

In addition, after every lobster season, Marine Resources Section staff will conduct semi-structured interviews with those lobster fishermen capturing lionfish to get their perceptions of the effect of lionfish on their catch and livelihoods. This will include information on the effect that they think the lionfish is having on daily fishing expenses.

As CPUE is not available for the finfish fisheries, the impact of the lionfish on commercial and recreational finfish fisheries on the Bermuda Platform will be monitored by conducting semi-structured interviews on a yearly basis with a subset of commercial and recreational fishers. Interviews will gauge the fishers' perceptions of the effect of lionfish on their catch, and in the case of commercial fishers on their livelihoods as well.

Monitoring Tourism

There are two main ways that the lionfish invasion can affect tourism:

- 1) A change in the structure and function of the reef ecosystem - negative change could affect the attractiveness of the reefs and the catch rate of important recreational fishery species and lead to fewer visitors; however, the presence of lionfish could actually become an attraction i.e. lionfish sightings or culling, and lead to more visitors;
- 2) An increased health risk – if the invasion spreads to popular dive/snorkelling sites and beaches, the risk of tourists being stung by lionfish would increase.

Monitoring indicators for tourism will be:

- Diver perceptions of the effects of lionfish on coral reefs
- Rate of envenomation among tourists

Information on these indicators will be collected by various agencies:

- A survey will be developed by the Lionfish Task Force that can be distributed by local dive operations to tourists in order to gather their perception on the effects of lionfish on coral reefs. This survey could also be made available online if this is deemed desirable.
- A questionnaire will be developed by the Lionfish Task Force that can be distributed to medical personnel at the KEMH, Government clinics and private doctor's offices to gather information on the number of envenomations among tourists per year. This survey will need to be approved by the Department of Health before it can be distributed.

Monitoring Human Health

As mentioned above, the risk to human health is a concern as an increase in lionfish abundance could increase the rate of envenomation among various sectors of the community. Individuals



who fish, dive and swim off the shoreline, and those who handle fish in the restaurant trade are likely at a greater risk of being stung.

The questionnaire developed to gather information on the rate of envenomation among tourists could also be used to collect information on the rate of envenomation among Bermuda residents, the long-term effects on those stung and the cost of treatment to the health system.

Monitoring indicators for residents will be:

- Rate of envenomation among different societal groups of residents
- Cost of treatment to the health system
- Trends in long-term effects on individuals who have been stung

This section expands on monitoring methods and will require continuous review as control measures are implemented.



5.06. PRIORITY V: DATA MANAGEMENT

Each component of the lionfish control plan will generate significant data and it is important to establish the capacity to store, analyze, and share data both between Bermuda's stakeholders and the greater regional lionfish effort. Currently, there is no central repository for lionfish related data and the plan recognises the importance of developing from the beginning a coherent action plan for identifying sources, mechanisms and analytical resources so that data is collected in a standardised method. This is yet to be done and has been emphasised within each component of the plan developers. The Lionfish Task Force will work with each organization involved with the programme to ensure that great care is taken to establish data protocols and data archiving at the start of each project.



Section 6. Public Health and Safety

Lionfish have venomous spines capable of inflicting a painful sting and sometimes more serious symptoms. As the lionfish population continues to grow, so does the likelihood of injuries through envenomation, to fishermen, divers, snorkelers, swimmers, and people whom otherwise handle or come into contact with lionfish.

It is essential that health and safety messages be provided to all sectors of the community. The Lionfish Control Plan will use its Education and Outreach programmes to provide people with information about safety practices to help minimise envenomation.

6.01 COMMUNITY HEALTH RISK

Lionfish have 13 dorsal spines that run the length of the fish's spine, 3 anal spines, and 2 pelvic spines, all capable of causing envenomation (coloured red in the Figure 1 below). Each spine is covered by a thin sheath of skin which, when depressed, compress a small pair of venom glands near the base of the spine (See Figure 2 below). The venom then travels from the glands through small depressions in the spines towards the wound. Aside from the extreme pain caused by the venom, a person, risks serious secondary infections as a result of a spine puncture, which may require aggressive antibiotic treatment and if the person has other health issues, envenomation may cause more severe reactions

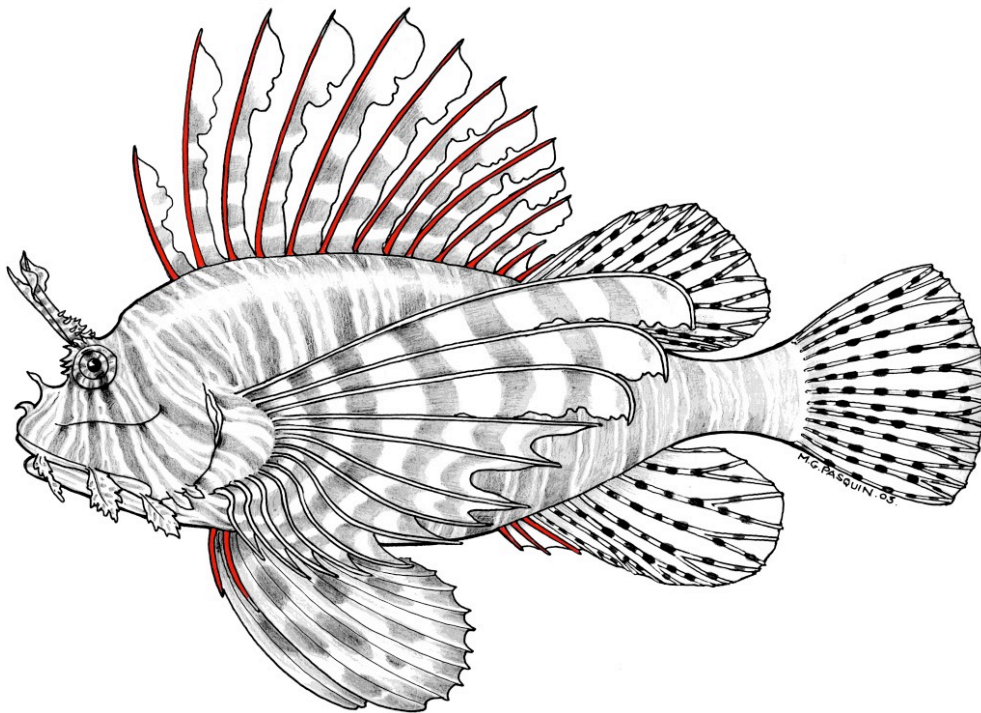


Figure 1 Illustrated by Michelle G. Pasquin

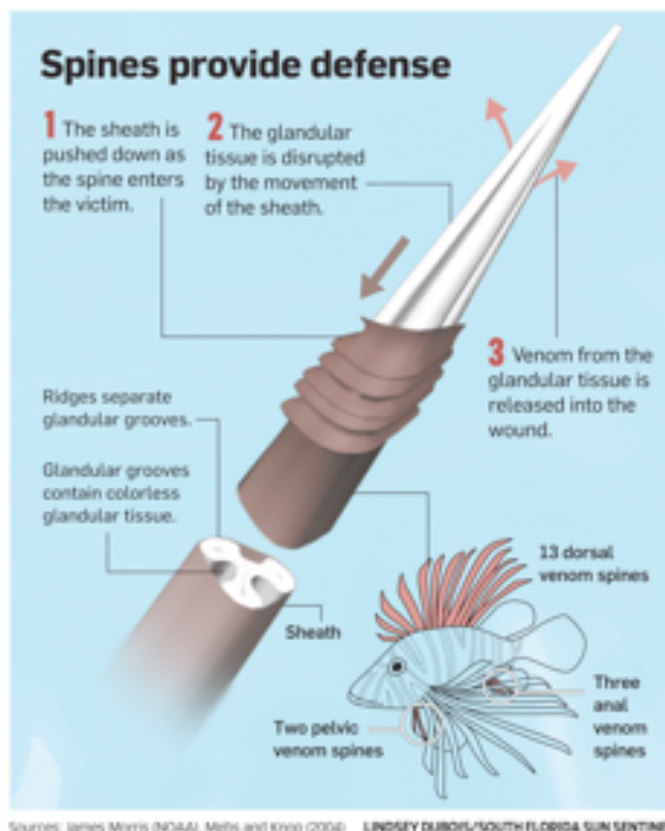


Figure 2 James Morris (NOAA), Mebs and Knop (2004) Courtesy of Lindsey Dubois/South Florida Sun Sentinel

6.02 FIRST AID

Lionfish venom is a proteinaceous neurotoxin, and heat will denature the venom quickly. The sooner a sting victim receives first aid treatment the better. The key to suppressing the sting is to find safe sources of heat, as this will relieve the pain and begin to denature the venom, possibly reducing more severe effects or complications. If possible, submerge the effected area in hot water for up to 90 minutes. Remember not to scald! A burn may be worse than the sting itself. Since numbness can be a sting symptom, so be sure to test the water temperature with an unaffected part of the body first, to prevent scalding. If in the field, potential heat sources may include:

- Bring a thermos of hot water when collecting lionfish.
- Nearby restaurants, marinas, or residences can usually heat water in an emergency.
- Vessel exhaust water or engine coolant systems may be a source of heat.



- Lay a wet shirt or towel over an engine block for heating, and then wrap affected area.
- Heat packs do not reach high enough temperatures to be effective, however, the reusable packs may provide relief for short periods (5-10 minutes).
- [Note: - Urine is body temperature and is therefore not effective.]

Lionfish spines are very sharp, but are not brittle and seldom break off when they enter and exit their victim. But if a fragment of the spine is present, remove it completely. As with any wound, the area should be cleaned, checked for possible debris, and always treated by a qualified medical professional.

Secondary treatment should be sought as soon as possible to reduce the risk of infections or deal with potential allergic reactions.

Over the counter painkillers can also be considered for additional pain relief (but ask your physician first before using them).

6.03 SAFE LIONFISH HANDLING PRACTICES

The single most important rule in approaching and handling lionfish is AWARENESS. People must be made aware that lionfish are now a part of our marine environment and that there is always the potential to encounter them not only in the water but also on boats and on shore after they have been captured.

The only proper way to handle lionfish is CAREFULLY!! The use of puncture proof or heavy gloves is advised. This will also protect your hands from the irritation the fleshy tentacles on the head may cause.

Puncture-resistant gloves are one of the most important tools in a lionfish collector's toolkit when considering the handling of fish above water. In contrast to standard working gloves, or even Kevlar gloves, which are designed to protect against cuts, specially designed and manufactured puncture-resistant gloves provide an added measure of protection against extremely sharp lionfish spines. While not 100% foolproof, use of these gloves will minimise stings and provide safer handling of fish during handling above water, and in preparing the fish for end-use.

If moving the fish, for example from a cooler, holding it by the head or lips will help avoid all spines. However, never assume the fish is dead so be extremely careful if you choose to grasp the lionfish by the head or lips as they may thrash about and potentially stick you.



Because of the potential for immediate swelling to any part of the body that is stung, rings should be removed first as a precaution before handling lionfish. You do not want to have a ring on with an inflamed hand. When preparing the lionfish for cleaning, wear heavy or puncture-resistant gloves, use a knife, and use a killing stab to the head in an attempt to kill the lionfish before handling. While the fish may appear dead, their spines may continue to pose a hazard, and you should not assume that the fish will remain immobilised.

Improper storage of lionfish can also provide an opportunity for severe stings. Storing fish in a well-marked and puncture proof container can help reduce these unnecessary risks.

When cleaning and filleting lionfish, the first order of business is to remove all the spines from the fish. Lay the fish flat on an appropriate cutting surface. With a pair of scissors or sharp knife, cut the spines off at the junction of the spine and the body of the fish along all rows of spines moving from the tail to the head. Place the removed spines carefully in a puncture proof container for safe disposal in a manner that does not present a hazard to others as these can still sting anyone that comes in contact with them. Once these spines are removed, the lionfish no longer poses a hazard, and can be filleted and cleaned as normal.

6.04 SAFE DIVING PRACTICES

This sub-section is not intended to provide or explain protocols for culling of lionfish at any water depth. They are general guidelines for safe scuba diving and snorkelling. In no way are these presented as protocols. Further, while this sub-section relates to both snorkelers and scuba divers, it is assumed that any scuba diving is always done by properly trained and certified divers.

Training is essential. All divers and snorkelers should be trained and certified to the target environment of the culling mission. All divers and snorkelers should only dive and snorkel at their level of training.



Planning is essential. Safe thorough, complete dive planning and briefing for both dive safety and dive mission are critical.

Communication is key. As with any dive activity, communication is absolutely essential, particularly when handling hazardous marine life. Be sure to actively communicate with your buddy every step of the way. Brief the dive before entering the water with the entire dive team present, including any surface support personnel. Prior to diving, discuss hand signals relevant to your activity, including signals for handing off lines or collection bags and alerting your buddy to an injury. Effective communication is always a fundamental element of safe diving.

Be prepared. If you have little or no experience catching lionfish, make sure you go through the appropriate instruction on how to safely capture and handle them. Consider going with an experienced culler of lionfish for your first outings.

Know your gear. Ensure that all your gear is in good working order prior to entering the ocean. Be very familiar with your gear's operation and that of your buddy. In addition, use appropriate collection equipment and adhere to any safety precautions particular to that equipment. For instance, if you are using a spear, follow established safety protocols; do not deviate as it may result in injury. The use of gloves in the water when spearing lionfish is not recommended, in order to discourage physical handling of lionfish in the water. However, if you are planning to net lionfish, the use of gloves is recommended.

Know your limits. Do not dive beyond your training or physical abilities. Do not push the boundaries or ignore decompression limits; no prize is worth risking your safety. For scuba divers, keep an eye on your gas and depth gauges; make sure you follow your dive computers or tables and that your surface intervals are sufficiently long.

Maintain a healthy respect. Do not forget that lionfish are hazardous marine life. Many people underestimate the threat of a lionfish envenomation. While rarely fatal, lionfish envenomation can cause extreme pain.

Know how to respond. Be prepared to handle a potential sting; should a sting occur while diving, do not panic. Make a controlled, safe ascent to the surface and administer first aid on the boat.

Maintain awareness. Always be aware of where your catch is, particularly when coordinating with your buddy. Be conscientious of the marine habitat, so as not to cause any damage to reefs. Maintain awareness of where lionfish are to avoid incidental contact. When approaching the lionfish, do so cautiously.

When spearing, a 3-prong “paralyzer” spear, no longer than 5 feet is the only spear that is currently permitted to use in Bermuda waters. Lionfish are generally not afraid of being approached, so smooth deliberate movements are called for. They will allow you to get to a



close range, so get as close as possible to them without touching the fish and release the spear. Once speared, place each catch into an appropriate containment unit (underwater), or bucket or cooler, above water, i.e. on the shore or boat, using the lid of the containment unit or sides of the bucket to pull the fish off directly into the container, and thus not touching them by hand. If free diving/snorkelling it would be beneficial to have surface support with whom the spear and the catch can be passed directly to for depositing in the on-board container. This will eliminate the need for in-water containment devices.

When considering underwater containment devices and removal equipment, most can be obtained commercially, however inventiveness and creativity in local and personal devices should not be dismissed. However, consideration for safety and effectiveness should always be exercised in the manufacture of personal devices.

6.05 SAFE BOATING PRACTICES

It is assumed that all watercraft will be operated in a safe and prudent manner and in accordance with Bermuda laws and standards, and that all vessels are seaworthy and safe.

While not required, it is prudent to carry cellular phones if available and special consideration should be given for the use of up-to-date commercially available navigation systems, such as GPS.

When going out for lionfish, there should be a minimum of two persons onboard.

Other important gear and supplies to consider having on board should be fresh drinking water, thick gloves, a knife, scissors, a pole or spear or stick, a bucket and if possible a cooler with ice (putting lionfish on ice will speed up their death and make for easier handling).

Ensure that your lionfish flag, provided by the DEP, is properly displayed.

Particularly when travelling at high speeds, ensure that any equipment and especially any containers with lionfish are secure as these pose a hazard if moving around the boat.

6.06 FURTHER ADVICE AND CONSIDERATIONS REGARDING STING TREATMENT

Although many injuries caused by lionfish can be non-life threatening, some injuries can develop into serious problems. Therefore, it is recommended that all lionfish injuries receive medical treatment by a physician as soon as possible. First Responders should be trained and equipped in the treatment and management of lionfish punctures and envenomation.

Training of hospital personnel and first responders will be a recommendation presented to the appropriate organizations on the island to ensure that appropriate treatment is administered. Incident data logging protocols should include envenomation events. Forms to be filled out



should be considered for envenomation data logging. For Bermuda, the “appropriate authorities” need to be determined and how the data will be used.



Section 7. Legal and Regulatory Considerations For Lionfish Management

7.01 REVIEW OF EXISTING LEGISLATION, POLICIES, AND PLANS

The two main methods identified in this Control Plan for managing lionfish are culling with spears in shallow water (<60ft, 18m)) and trapping of lionfish in deep water (>150ft, 45m).

The Fisheries Act 1972, and the Fisheries Regulations 2010 and various Fisheries Orders made under the Act, govern the taking, possession, and sale of all marine organisms around Bermuda. A license is required for both spearfishing and trapping, and other restrictions also apply to these activities.

Spearfishers are not permitted to use a speargun or an aqualung (SCUBA tank) for taking fish and can be penalised even if they are found in possession of fish on a vessel in which an aqualung (SCUBA tank) is present or if they are found with a spear and an aqualung (SCUBA tank) together in their possession on a boat or while swimming. Spearfishers also cannot spearfish within one nautical mile of shore and can only take two fish of any one species per day (except lobster, which they are not allowed to take by spear at all). In addition, as this activity is only recreational, spearfishers are not permitted to sell their catch.

Trapping is only conducted on a commercial basis and is currently limited to the capture of lobsters (i.e. the Caribbean spiny lobster, *Panulirus argus*, and the spotted spiny lobster or guinea chick, *Panulirus guttatus*). The use of fish pots was banned in 1990. Current policy also prohibits lobster fishermen from selling fish caught in their lobster traps.

In addition to the above restrictions, both spearfishers and lobster trap fishermen are prohibited by Order from fishing in twenty-nine permanently closed dive sites and two areas seasonally closed from 1st May to 31st August every year to protect fish spawning aggregations. A prohibition on fishing on black grouper (*Mycteroperca bonaci*) spawning aggregations in a smaller part of both seasonally protected areas is extended until the 29th November each year by a notice published in the Official Gazette.

Shallow Water Culling

Since 2008, the Department of Environmental Protection has authorised individuals to spear lionfish on SCUBA within one nautical mile of shore in an effort to protect native fish stocks. No amendments to legislation were necessary as the Fisheries Act contains a provision that allows the Director to issue permits exempting adherence to the Fisheries legislation for a number of purposes, including for the purposes of the protection of fish and of scientific research. Current terms and conditions of a “lionfish culling permit” are:

- The Permit is valid from 1 September 2012 to 31 August 2013.



- The permit holder must have attended a special training course provided by the Ocean Support Foundation on capturing and handling Lionfish.
- The only type of spear permitted for culling Lionfish under the terms of this permit will be a 3-prong “paralyzer” tip on a pole with a maximum length of 5 ft.
- No other species may be targeted in conjunction with permitted Lionfish culling activity.
- Permitted spears may be used anywhere on the Bermuda platform (including within 1 nautical mile of the shore) for the purposes of taking Lionfish only. Any person in the water with a spear within 1 nm of the shore and in possession of any fish other than Lionfish, whether in the water or on an attending boat, is in violation of the conditions of this permit.
- Permit holders may use permitted spears in conjunction with SCUBA to cull Lionfish only, provided they have a SCUBA certification from a recognised training agency. A person in possession of a SCUBA tank, either on their person or in an attending boat, may not be in possession of any fish other than Lionfish, either on their person or in an attending boat.
- The special Lionfish flag provided with the permit must be flown from a vessel or the shore when culling Lionfish.
- The permit holder must have the plastic disc issued with this permit and valid photo identification with them on every Lionfish culling trip.
- For safety reasons the permit holder should be accompanied by another person, also trained in handling Lionfish.
- The permit holder should also file a float plan with Bermuda Radio every time he/she goes on a Lionfish culling trip.
- A record of all Lionfish caught must be submitted to the Department through the Ocean Support Foundation.
- When spears are not being used, they must be stored in a secure location.

The “lionfish culling permit” holder is also required to sign the below waiver, which was approved by the Attorney General’s Department:

I, the undersigned, acknowledge that spears can cause serious injury and that spear fishing is an inherently dangerous activity. I also acknowledge that Lionfish (*Pterois spp.*) have venomous spines that can inflict a serious sting and/or cause serious injury or death, even after the fish are dead. I confirm that I have undertaken training in the safe handling of Lionfish and accept full responsibility for all risks associated with the inherently dangerous activity of culling Lionfish. I furthermore agree to hold harmless the Bermuda Government from all actions, proceedings, claims, and demands that I may have for injury (including injury resulting in death) that may result from the culling of Lionfish.



Cullers have been advised that they could face severe fines for violating the terms and conditions of their culling permit.

In addition to the permitted “lionfish cullers”, spearfishers who have a regular spearfishing license can also capture lionfish in shallow water. While not exempted from the regulations governing their activities, a policy allowing these spearfishers to capture as many lionfish as possible in one day was instituted in 2011.

Deep Water Trapping

As a large proportion of the lionfish population in Bermuda is found in deep water where lobster trapping occurs (>150ft), lobster fishermen have been catching numbers of lionfish in their traps. Because of this, and in an effort to create a market for these fish, the DEP amended the policy regarding the sale of fish caught in traps to permit lobster fishermen to sell the lionfish only.

The Department also plans to run an experimental trap project to specifically target lionfish using modified lobster traps. Lobster fishermen will be licensed under the Fixed Fishing Gear Regulation to participate in the experiment.

7.02 CONSIDERATION FOR LEGAL AND REGULATORY MODIFICATIONS

Shallow Water Culling

The current permitting system for lionfish cullers seems to be working well and the plan is to continue with this approach for this group. In addition, special umbrella permits will be issued to dive shops and organizations such as the Ocean Support Foundation and the Bermuda Institute of Ocean Sciences that allow the inclusion of many individuals (i.e. staff and tourists) on one permit. Each person included under the permit will be required to obtain a plastic lionfish disc and flag and adhere to the other terms and conditions of the permit. Consideration is also being given to only allowing those included under organizations to cull in protected areas, as this would likely reduce the risk of illegal fishing in these areas.

Deep Water Trapping

Commercial lobster fishermen will continue to be encouraged to retain and sell any lionfish captured in their traps. Additionally, if high catch rates of lionfish and low levels of other finfish bycatch can be obtained during the lionfish trapping experiment, the DEP will look to establish a small lionfish fishery to increase the rate of lionfish removal from the reefs and thus increase the availability of this product on the local market. Again, fishermen will need to be licensed under the Fixed Fishing Gear Regulation to participate in this fishery and will have to be carefully selected to reduce the risk for abuse of the privilege. Lionfish trapping will not be permitted in marine protected areas.

Aquarium Trade



The importation of marine organisms into Bermuda is not permitted unless it is done under a special license, and the DEP has not allowed the importation of such organisms for the aquarium trade. Therefore, importing lionfish for this purpose will certainly be prohibited. However, there may be some who will see the presence of lionfish in local waters as an opportunity to collect them for trade among aquarium enthusiasts on the Island. This could exacerbate the lionfish problem in Bermuda if such individuals then dispose of unwanted lionfish. To counteract this, consideration is being given by the Department of Conservation Services to introducing a new Invasive Species Act that would include a provision to prevent the care for, support, or breeding of lionfish. Live lionfish displays will only be allowed for research and public education purposes.



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BERMUDA LIONFISH TASK FORCE MEMBERS

Department of Conservation Services

Department of Environmental Protection

Ocean Support Foundation

Bermuda Aquarium, Museum and Zoo

Bermuda Zoological Society

Bermuda Institute of Ocean Sciences

Bermuda Underwater Exploration Institute

Groundswell

Reef Environmental Education Foundation

Bermuda Blue Halo Project

The Bermuda National Trust

Bermuda Ocean Explores

Dolphin Quest

Bermuda Dive Association

Triangle Diving

Blue Water Divers & Water Sports

Dive Bermuda

Fantasea Diving & Watersports

Tucker's Point Diver & Water Sports Centre

Bermuda Commercial Fisheries Council

Bermuda Department of Tourism

Bermuda Marine Resources Board

Local Resident Divers



ACRONYMS

AGRRA Atlantic and Gulf Rapid Reef Assessment

BAMZ Bermuda Aquarium, Museum and Zoo

BIOS Bermuda Institute of Ocean Sciences

BSAC Bermuda Sub Aqua Club

BUEI Bermuda Underwater Exploration Institute

BZS Bermuda Zoological Society

CEP Caribbean Environment Programme

CPUE Catch-per-unit-effort

DCS Department of Conversation Services

DEP Department of Environmental Protection

E&O Education and Outreach

GCFI Gulf and Caribbean Fisheries Institute

GPS Global Positioning System

IAS Invasive Alien Species

JNCC Joint Nature Conservation Committee

KEMH King Edward Memorial Hospital

MPA Marine Protected Area

NGO Non Governmental Organization

NOAA National Oceanic Atmospheric Administration

OSF Ocean Support Foundation

REEF Reef Environmental Education Foundation

UKOT United Kingdom Overseas Territories

VHF Very High Frequency