

Invasive Lionfish in the Marketplace: Challenges and Opportunities

Invasor Pez León en el Mercado: Retos y Oportunidades

Lionfish Envahissantes sur le Marché : Défis et Opportunités

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ABSTRACT

Invasive lionfish (*Pterois volitans/miles*) threaten biodiversity and can negatively impact native reef fish communities that cultures and economies from North Carolina to Venezuela rely on for their livelihoods. Invasive lionfish control strategies, including commercial harvesting, are needed to mitigate local impacts. On November 4th 2013, 44 representatives from federal and state agencies, academic and scientific institutions, non-government organizations, law, restaurants, seafood distributors, media, and fishers participated in a workshop held during the 66th annual meeting of the Gulf and Caribbean Fisheries Institute in Corpus Christi, Texas to identify the challenges of harvesting and distributing invasive lionfish as a means of control. Harvesting invasive lionfish for control presents several challenges including difficulty of capture, threat of envenomation, and potential liability associated with ciguatera fish poisoning during invasive lionfish consumption. Never before have coastal managers in the western Atlantic faced the challenge of controlling an invasive reef fish. This document serves as the workshop proceedings and:

- i) Summarizes the current state of knowledge regarding the prevalence of ciguatera in invasive lionfish and the potential for liability, harvesting methods, supply and distribution, and end-uses,
- ii) Delivers a series of consensus statements developed by all workshop participants including agreement that harvesting invasive lionfish is feasible and necessary and that the seafood industry and seafood health regulators should treat invasive lionfish the same as other reef fish with regards to ciguatera, and
- iii) Identifies invasive lionfish harvesting and ciguatera research needs and priorities.

KEY WORDS: Lionfish, harvest, Gulf and Caribbean Fisheries Institute, ciguatera

INTRODUCTION

Invasive lionfish (*Pterois volitans/miles*) have become the most abundant top-level predator on some reefs of the southeastern U.S., Caribbean Sea, and Gulf of Mexico where they threaten biodiversity and community composition and function (Morris et al. 2012). Invasive lionfish are established in all major marine habitat and substrate types from 0 m to > 300 m depth (Morris et al. 2012). Consequently, researchers and managers have agreed that eradication is unrealistic at this point. Localized control has proven effective at reducing invasive lionfish abundance (Akins 2012). However, these efforts are not always sustainable or practical. Therefore, innovative and sustainable management approaches are required to maintain invasive lionfish populations at densities where their ecological and socioeconomic impacts are minimized.

On November 4th, 2013, the National Ocean and Atmospheric Administration (NOAA), the Reef Environmental Education Foundation (REEF), and the Gulf and Caribbean Fisheries Institute (GCFI) organized a workshop to identify the challenges of harvesting and distributing invasive lionfish as a means of control. The workshop – *Invasive Lionfish in the Marketplace: Challenges and Opportunities* – was held during the 66th GCFI meeting in Corpus Christi, Texas and was attended by 44 representatives (see Acknowledgements for a complete list) from federal and state agencies, academic and scientific institutions, non-government organizations, law, restaurants, seafood distributors, media, and fishers.

The objective of the workshop was to review the current state of knowledge, document challenges, assess opportunities, identify research needs, and generate consensus statements regarding invasive lionfish harvest, distribution, consumption, and other end-uses. The workshop was partitioned into five objective-focused sessions including invasive lionfish and ciguatera, legal aspects of ciguatera, harvesting invasive lionfish, case studies of invasive lionfish in the marketplace, and invasive lionfish supply and distribution. Sessions consisted of oral presentations and group discussions. Consensus statements were developed and agreed upon by the workshop participants and research needs and priorities were identified. The workshop was facilitated by Dr. James Morris (NOAA) and recorded by Alex Bogdanoff (NOAA). This document serves as a summary of the presentations and discussions held during the workshop.

WORKSHOP SESSIONS

Objective: Summarize our state of knowledge regarding invasive lionfish and ciguatera.

Presenters and presentation titles:

- i) Patricia Tester, Ph.D. (Senior Scientist, NOAA contractor) – *Ciguatera fish poisoning in the Caribbean*
- ii) Christie Wilcox (Ph.D. candidate, University of Hawaii) – *Ciguatera and scorpionfish venom interactions*
- iii) Bernard Castillo II, Ph.D. (Assistant Professor of Chemistry, University of the Virgin Islands) – *Invasive lionfish and ciguatera in the USVI*
- iv) Nicholas Diaz (Secretary General, CRPMEM de Guadeloupe) – *Invasive lionfish ciguatoxicity risk assessment in the French West Indies*

In an effort to develop invasive lionfish control programs, many Caribbean nations have launched promotional campaigns such as “Eat Lionfish” and “Let’s eat them to beat them”. These campaigns, which encouraged the harvest, distribution, and consumption of invasive lionfish on local and commercial scales, were supported by research demonstrating that invasive lionfish are edible and have higher levels of healthy omega-3 fatty acids than some frequently consumed native marine fish species (Morris et al. 2011). Furthermore, invasive lionfish have a flaky white meat with a taste comparable to grouper.

Invasive lionfish are the first invasive marine fish to be promoted as a food fish in the temperate and tropical western Atlantic. In 2011, the U.S. Food and Drug Administration (FDA) tested invasive lionfish from St. Croix (STX), U.S. Virgin Islands (USVI), a known ciguatera hotspot (ciguatera-endemic region), for the presence of ciguatoxins (CTXs) (see Robertson et al. 2013). Ciguatoxins are naturally occurring toxins, produced by benthic dinoflagellates in the genus *Gambierdiscus*, which bioaccumulate through the food-web from algae, to herbivorous fish, to carnivorous fish, and ultimately to humans (GEOHAB 2012). In humans, CTXs cause ciguatera fish poisoning (CFP), which is the most common non-bacterial food borne illness related to fish consumption (Hokama 1993, Lange 1994). Ciguatera fish poisoning is rarely fatal (< 0.01% of cases) but can result in severe gastrointestinal, neurological, and cardiovascular health issues lasting from weeks to even years (Friedman et al. 2008).

As part of the 2011 FDA study, Dr. Bernard Castillo tested 27 invasive lionfish from three locations around STX (20 western, six northern, and one eastern) and found that 40% of the western, 17% of the northern, and 0% of the eastern samples tested positive for CTXs. Furthermore, 15% and 0% of the western and northern samples were above FDA guidance for Caribbean CTXs (≥ 0.1 ppb C-CTX-1), respectively (see Robertson et al. 2013). Based on the results of this study, the FDA released a guidance

document for industry for purchasing reef fish species associated with the hazard of CFP in 2013, which included lionfish in a long list of reef fish species that have the potential to cause CFP (FDA 2013).

Since 2011, Dr. Castillo has also tested 124 barracuda, 22 schoolmaster, and an additional 126 invasive lionfish from St. Thomas (STT) and St. John (STJ), USVI for CTXs. This study showed that 98% of the barracuda, 100% of the schoolmaster, and 43% of the invasive lionfish tested positive for CTXs and 13% of the invasive lionfish were above FDA guidance. CTX levels for the barracuda and schoolmaster are unknown. In summary, of the 153 invasive lionfish tested from the USVI (STX, STT, and STJ), 40% had detectable levels of CTXs and 12% were above the FDA guidance (≥ 0.1 ppb C-CTX-1) (see Robertson et al. 2013). According to Dr. Castillo, there have been no known incidences of ciguatera reported from invasive lionfish consumption in the USVI up to January 15th 2014.

In the French West Indies (FWI), Nicholas Diaz conducted a similar study with 30 invasive lionfish from northern Guadeloupe, 30 from southern Guadeloupe, 5 from Saint-Martin, and 55 from Saint-Barthelemy. All Guadeloupe and Saint-Martin samples tested negative for CTXs. However, 49% of the Saint-Barthelemy samples tested positive and 40% were above the recommended exposure threshold for Pacific CTXs (≥ 0.01 ppb P-CTX-1). It is unknown if any of the Saint-Barthelemy samples that tested positive for CTXs were above the FDA guidance for Caribbean CTXs (≥ 0.1 ppb C-CTX-1). In addition to CTX testing, 106 members of the FWI community volunteered to consume invasive lionfish and have the results recorded. None of the volunteers became ill and the general consensus was that invasive lionfish tastes very good. According to Nicholas Diaz, there have been no known incidences of ciguatera reported from invasive lionfish consumption in the FWI up to January 15th 2014.

Ciguatera fish poisoning is a serious health concern throughout much of the Caribbean. Several important aspects and even uncertainties exist within our current state of knowledge with regards to CFP epidemiology, ecology, and toxicology. For example, approximately 50,000 cases of CFP are reported globally each year (Lewis 2001, Quod and Turquer 1996). However, it is believed that > 90% of cases go unreported making it difficult to identify geographic locations of concern and to calculate accurate frequency rates (Arena et al. 2004, Pearn 2001). Seven *Gambierdiscus* spp. are ubiquitous in the southeastern U.S. and Caribbean (Tester et al. 2013). However, three species are toxic and their toxicity levels, abundances, and distributions are highly variable (Tester et al. 2013). This variability is due to *Gambierdiscus* spp. limitation by temperature (Tester et al. 2010), local ecology, physiology, and habitat characteristics. Depending on the combination of these factors, microhabitats or “CTX hotspots” can exist (Tester et al. 2013).

It is unknown if toxicity varies by fish species or if certain fish species are more frequently toxic than others. More comprehensive studies are needed however, CTX testing is expensive and time consuming (on the order of days/handful of samples). Dr. Patricia Tester revealed that the recent development of a competitive fluorescence-based synaptosome binding assay may help reduce analysis time and cost. Recent studies by Christie Wilcox suggest that compositional similarities between scorpionfish venom toxins and CTXs may cause false positives for CTX in cell cultures, mouse bioassays, neuroblastoma assays, rapid hemolytic assays, and guinea pig atrial assays. False positives do not occur when using liquid chromatography-mass spectrometry (LC-MS). Further research is needed to quantify the frequency of false positives.

The CTX exposure threshold recommended by the FDA is also an important factor to consider. The exposure threshold is simply the minimum CTX concentration in a fish that is believed to elicit adverse human health effects. In the Caribbean and Pacific, exposure thresholds are 0.1 ppb C-CTX-1 (Vernoux and Lewis 1997) and 0.01 ppb P-CTX-1 (Lehane and Lewis 2000), respectively. These values were derived by applying a 10X safety factor (accounting for individual human risk factors, uncertainty in the amount of fish consumed, and uncertainty in assay accuracy) to estimated threshold contamination levels for Caribbean and Pacific CTXs. Estimated threshold contamination levels were supported by a literature review that identified the lowest CTX concentration that has caused adverse human health effects (see Dickey et al. 2008, Dickey 2008). By these standards, any fish containing \geq 0.1 ppb C-CTX-1 could potentially result in CFP. Conservative recommendation levels for food fish are important when it comes to toxins and human health. However, little to no laboratory evidence validates the CTX exposure thresholds recommended by the FDA.

Legal Aspects of Ciguatera

Objective: Summarize the legal challenges that distributors, restaurant owners, and resource managers may face by promoting invasive lionfish consumption.

Presenter and presentation title:

- i) Jaime V. Biaggi, Ph.D., J.D. (Attorney, Bufete Biaggi Busquets & Mari Rocca, Puerto Rico) – *Legal aspects of ciguatera fish poisoning in Puerto Rico*

The manner in which the Supreme Court of Puerto Rico has handled CFP cases has changed drastically over the years. Prior to 1990, if a customer in a Puerto Rican restaurant became ill with CFP, he or she was entitled to compensation if they could prove that they had eaten fish in the restaurant and developed CFP symptoms shortly thereafter. The plaintiff did not need to prove a negligent act or omission on the part of the defendant in order to win the case. This was because the Supreme Court of Puerto Rico had applied the doctrine of “implied warranty” or

“absolute responsibility”, suggesting that a public establishment is held to the standard that the food they serve is clean, wholesome, free from impurities, and fit for human consumption. To avoid costly court fees and the almost certain ruling in favor of the plaintiff, CFP cases were routinely settled out of court. However, the use of the “implied warranty” doctrine was based on precedence set by two cases which involved food poisoning as a result of human manufactured food products (Castro vs. Payco, Inc., 75 DPR63 (1953) and Mendoza vs. Cervecería Corona, Inc., 97 DPR499 (1969)) (see Biaggi 1990).

In 1990, as defense counsel for the insurance industry, Jamie V. Biaggi argued two CFP test cases before the Superior Court of Puerto Rico. The defense argued that:

- i) CFP is caused by a naturally occurring toxin not developed by human hands and/or the mishandling of food.
- ii) “Implied warranty” was established based on the precedence set by two test cases involving manufactured food products. However, fish is not a manufactured food product and can’t be treated equally.
- iii) There is no possible way to prevent the damages of CFP.
- iv) Negligence on the part of the defendant was impossible because human hands play no part in CFP.
- v) CFP is caused by a natural process. No person was responsible for the damages of CFP.

Both cases were ruled in favor of the defendants by the Superior Court of Puerto Rico and supported by the Supreme Court of Puerto Rico who stated:

“There is no way to prevent the damage that a consumer might suffer. The only way to prevent the damages would be total abstinence. The doctrine of ‘absolute responsibility’ does not apply in cases involving ciguatera fish poisoning, this doctrine was developed only to protect the consumer from careless manufacturers”.

(Mendez Corrada vs. Ladi’s Place, 90 JTS 125, 1990) (see Biaggi 1990).

The basis for this winning argument was that ciguatera fish poisoning occurrence is spatially and temporally variable throughout the Caribbean and Pacific and that over 400 fish species have the potential to become ciguatoxic (Halstead 1967). Therefore, fishers, wholesalers, distributors, restaurant owners, and all persons involved in the fishing industry cannot be held responsible if their products contain CTXs. For additional assurance, Jaime V. Biaggi suggests a generalized caution statement referring to all marine reef fish collectively, similar to that of a shellfish toxicity warning, be displayed within all establishments that serve fish and on all fish products. A CFP caution

statement could read as follows:

“Ciguatera fish poisoning has been attributed to many fish species from subtropical and tropical waters of the Pacific, Gulf of Mexico, western Atlantic, and Caribbean Sea. The consumption of fish products from these water bodies has some associated risks.”

Harvesting Invasive Lionfish: Methods, Challenges, and Ideas

Objective: Summarize current invasive lionfish harvesting tools and techniques and identify markets and supply chains.

Presenter and presentation title:

- i) Lad Akins (Director of Special Projects, REEF) – *The lionfish invasion*

Invasive lionfish are the first non-native marine fish to become established in the U.S. and Caribbean, and have been found in every major marine habitat from 0 m to >300 m depth between North Carolina and South America (Morris et al. 2012). Invasive lionfish do not recognize borders, jurisdictions, or MPA boundaries and should therefore, be of concern to all citizens in the invaded range. Even with high abundances, a suite of challenges exist, with regards to harvesting techniques and their utility, which are dampening the development of a sustainable market. Sustained effective removal efforts are critical in reducing local invasive lionfish densities, thus minimizing invasive lionfish impacts.

Invasive lionfish are being caught on hook-and-line. These captures are uncommon, generally confined to deeper waters (70 m - 150 m), and are almost always as by-catch (i.e., not the targeted species). Lionfish are ambush predators and are not likely to chase down baited hooks outside their immediate areas. Therefore, hook-and-line is not an effective large scale invasive lionfish harvesting technique.

Invasive lionfish are also being caught as by-catch in lobster traps. In fact, they are found in 1/4 - 1/3 of Florida Keys deep-water traps and are the second highest by-catch species by number within the industry. However, lobster catch is reduced by more than half when invasive lionfish are present within a trap and lobster fishers are getting between \$3.50 - \$6.00 USD/lbs. for whole invasive lionfish compared to ~ \$10.69 USD/lbs. for lobster (FFWCC 2013). Lionfish prefer complex structures, such as coral heads and overhangs, and it is believed they are utilizing lobster traps for habitat. Trapping shows high potential as an effective large scale harvesting method. Further research and development is required to create a trap that is efficient at catching invasive lionfish while minimizing capture of unintended by-catch.

Targeted removals by SCUBA divers and snorkelers, using spears and nets, have been the most effective

methods for removing large quantities of invasive lionfish at local scales. For example, over 5,000 invasive lionfish have been removed from the Florida Keys since 2010 through annual derbies hosted by REEF. This technique is also the most expensive in terms of time, money, and safety and carries additional challenges. For example, SCUBA diving and snorkeling already have high associated costs and health risks (gear, dive trips, etc.). Lionfish have venomous spines and are highly mobile adding an additional safety factor to consider. Invasive lionfish handling and collection training can help reduce the potential risks for envenomation and improve capture efficiency. Local control is confined to specific geographic locations requiring regular visits to maintain reduced invasive lionfish populations and their associated impacts. On a local scale, targeted removals are a highly effective harvesting technique; but for long term control, removal efforts must be sustained. Partnerships and collaborations between derby hosts, collectors, distributors, and restaurants will help maintain regular removal events providing dependable supplies of invasive lionfish.

Additional end-uses for invasive lionfish other than harvesting for food also exist. They can be used in the curio (ornamental) trade as jewelry, such as earrings and necklaces, as taxidermy for center pieces, wall hangings, desk art, etc., and in the aquarium trade. Although the aquarium trade and the release of unwanted lionfish into the ocean is one potential mechanism for starting the invasion, invasive lionfish are well enough established that the few individuals that could re-enter the wild, through escape or release, would not likely impart recognizable ecological and socioeconomic impacts.

A key consideration with regards to an invasive lionfish market (food fish, curio trade, and aquarium trade) is the difference between lionfish and invasive lionfish. Lionfish refers to the population that inhabits and is native to the Indo-Pacific. Invasive lionfish refers to species found in the western Atlantic, Gulf of Mexico, and Caribbean Sea. Indo-Pacific native lionfish do not impart the same ecological and socioeconomic impacts in their native range as they do in their invaded range. As the invasive lionfish market develops, it is extremely important to be cognizant of where lionfish are supplied from and it is highly encouraged to *ask specifically for invasive lionfish*. Trading lionfish and lionfish parts from their native range is counterproductive. Lastly, miscommunication and misinformation, however small it may be, can cause resonating impacts that can impede and even stop invasive lionfish control efforts. Therefore, it is necessary to communicate vetted information at all times.

Invasive Lionfish in the Marketplace: Case Studies

Objective: Promote collaborations and networking, identify supply chain weaknesses, and develop solutions.

Presenters and presentation titles:

- i) Brian Barber (Sous Chef, *Fleet Landing Restaurant*, Charleston, SC) – *A chef's perspective on invasive lionfish*
- ii) Ryan Chadwick (Owner, *Norman's Cay and Grey Lady Restaurant*, New York, NY) – *Invasive lionfish in the Big Apple!*
- iii) Travis Riggs (Seafood representative, *Sea to Table*, San Antonio, TX area) – *The Sea to Table experience with invasive lionfish*

Brian Barber has been serving invasive lionfish as a daily or weekly fresh catch for the last few years. In addition to creating unique dishes, Brian devotes time to educate and train his wait staff on what invasive lionfish are and their associated impacts. Brian purchases whole invasive lionfish from local spearfishers for \$6.00 USD/lbs., fillets them in house, and sells most dishes around \$28.00 USD. In comparison, several snapper dishes are menu priced around \$26.00 USD. Brian says that he really enjoys seeing the large amount of repeat customers that come back just for invasive lionfish. In fact, it has become so popular that he sells out every week and doesn't have enough fish to meet the demand.

Ryan Chadwick has recently begun serving invasive lionfish on his menus. Ryan's experience differs from Brian Barbers in that invasive lionfish are not local (invasive lionfish can't survive the winter temperatures above North Carolina, see Kimball et al. 2004) and need to be shipped. In an effort to satisfy current customer demand and to create additional customer interest, Ryan and a small team have been flying to-and-from the Bahamas to personally collect, package, and bring their catches home to New York City. Ryan admits this is not the most efficient business plan but he hasn't found better options and his customers want it now and are willing to pay for it. Due to associated costs, Ryan pays approximately \$15.00 - \$16.00 USD/fish and must sell dishes for at least \$44.00 USD. Ryan and his team are investigating more efficient supply lines in the Caribbean and North Carolina. His biggest challenge is connecting with local groups who can provide large enough quantities of fish to keep costs down and who can do it on a regular schedule. Ryan and his team are creating a short educational video for their restaurant website that addresses the invasive lionfish issue and why a sustainable market is a good idea. Ryan hopes the video, which he shared during the workshop, will help stimulate consumer interest and further promote the market.

Travis Riggs explained the vital role his company has played in establishing invasive lionfish supply chains. *Sea to Table* is a family run business that links fishers from local small-scale sustainable wild fisheries with restaurants and the public nationwide. *Sea to Table* expedites the shipping process by shipping directly from the docks to your door the following day. *Sea to Table* can also facilitate custom invasive lionfish orders less than the

minimum 25 lbs. However, fish quality must be superior to match the cost. Travis began his presentation by surprising the workshop participants with ceviche made with invasive lionfish supplied by *Sea to Table*. To the best of our knowledge, each participant had a portion, some even had two, and the general consensus was that invasive lionfish is a light, fresh tasting flaky white fish. Travis pointed out that a lot of chefs he works with are promoting and utilizing invasive lionfish as an artisanal food. For example, some restaurants deep fry and serve the fish whole creating a truly unique presentation. Travis feels this is a great promotional technique to create buzz within our current food culture and it can also help elevate prices. Travis mentioned there are not enough mid-range restaurants serving invasive lionfish and not enough inexpensive sources, processing facilities, and/or practices. Once these niches are created, it will help this market explode. In Travis' experience, paying under \$6.00 USD/invasive lionfish is a good target price. However, it raises the question – how much is the public willing to pay for a “green meal”?

Invasive Lionfish Distribution: How to Get from There to Here?

Objective: Promote collaborations and networking, identify supply chain weaknesses, and develop solutions.

Presenters and presentation titles:

- i) David Johnson & Gary Groomes (President and Founder & Vice President, *Traditional Fisheries*) – *Invasive lionfish distribution experiences and challenges*
- ii) Bethany Young (Public Relations and Marketing Assistant, *Rainforest Seafood*) – *Invasive lionfish distribution experiences and challenges*

David Johnson started *Traditional Fisheries* about three years ago, partnering with Gary Groomes shortly thereafter, in an effort to provide income to fishers, contribute to invasive lionfish control, and to earn a living. Over 35 tons of invasive lionfish have been harvested, processed, and distributed through *Traditional Fisheries* and their co-ops. *Traditional Fisheries* sources invasive lionfish primarily from the Yucatan region however, several logistical and financial challenges are prohibiting further expansion. For example, *Traditional Fisheries* ships using FedEx, which can take up to 36 hours for a shipment to reach its destination. FedEx also has packaging rules and regulations for dry ice and gel-packs. Even though FedEx works very well for *Traditional Fisheries*, it is very expensive. Furthermore, FDA requirements for shipping and distributing food fish have been known to slow the process down and all fishery co-ops must be FDA compliant. The most impeding aspect is the lack of capital and the lack of market recognition. In an effort to minimize invasive lionfish impacts and to raise capital, David and Gary are currently working with an electrical engineer

from the University of New Orleans to write an invasive lionfish identification algorithm for an invasive lionfish selective trap. *Traditional Fisheries* is also expanding into the microbeer market with the “lionfish lager”, which features an invasive lionfish image and fast-facts on the label but is not brewed with any invasive lionfish parts. In terms of operation, *Traditional Fisheries* sells invasive lionfish for \$15.00/lbs. for fillets and is sold in a minimum package of 20lbs. Gary explained that packages greater than 100 kg can decrease the costs of shipping to about \$2.00 USD/lbs., which can help cut costs. However, the demand is not currently large enough to consistently ship 100 kg packages. Gary also made a point, which was supported by Brian Barber, Ryan Chadwick, and Travis Riggs, that frozen invasive lionfish taste exactly the same as fresh and the difference in texture is negligible.

Bethany Young shared *Rainforest Seafood*'s experiences with distributing invasive lionfish in the Caribbean. *Rainforest Seafood* is one of the largest seafood providers in Jamaica and has the infrastructure to maintain sufficient invasive lionfish supply. However, in Jamaica and other Caribbean nations, there is low demand for the fish due to health concerns and high costs. For example, many Jamaicans are concerned whether the fish is safe to consume due to CFP and many mistakenly believe it to be poisonous. In contrast, some Jamaican men believe them to be aphrodisiacs. Invasive lionfish costs about \$3.00 USD/fish, which is expensive in the Caribbean. In an effort to increase awareness and education on invasive lionfish, *Rainforest Seafood*, the University of the West Indies, and other organizations have hosted educational as well as tasting and sampling events throughout Jamaica. *Rainforest Seafood* does not provide wide scale distribution of invasive lionfish and only sources by special request. *Rainforest Seafood* will ship direct to consumers, but it is very expensive and they need to supply a high quality product to match the costs. Depending on the request, invasive lionfish are either flash frozen or vacuum packed and shipped on ice. *Rainforest Seafood* does not currently export to the U.S., but their FDA compliant plant in Roatan, Columbia does. A new FDA compliant processing facility is being built in Kingston, Jamaica, which can ship to the U.S., but it is uncertain if this facility will be processing invasive lionfish.

WORKSHOP OUTCOMES

Consensus Statements

Based on the information presented and discussed during the workshop and until further evidence suggests otherwise, the 44 workshop participants are in agreement that:

- i) An invasive lionfish food fish market is practical, feasible, and should be promoted.
- ii) Alternative invasive lionfish end-uses, such as the curio and aquarium trade, are also viable markets.
- iii) Regarding consumption and the risk for CFP,

invasive lionfish should not be treated differently than other fish species.

- iv) A general caution statement (referring to all fish species collectively) should be displayed within all establishments that serve fish and on all fish products.
- v) Local control is effective at minimizing invasive lionfish impacts at local scales and should be encouraged where possible.
- vi) Managers are encouraged to consider regulatory amendments in MPAs and other no-take areas to allow the removal of invasive lionfish.

Invasive Lionfish Harvesting and Ciguatera Research Needs and Priorities

- i) Comparative risk assessments.
 - a. Are invasive lionfish more toxic than other reef fish?
 - b. Are invasive lionfish more frequently toxic than other reef fish?
 - c. Fish length/weight-CTX correlations.
 - Does this vary by fish species?
 - d. Diet vs. toxicity studies.
 - Does this vary by fish species?
 - e. CTX toxicity variability by depth.
 - Are certain depths ‘safer’ than others?
 - f. Identify locations and causes of CFP “hotspots”.
 - g. Are high lipid fish at more of a risk for carrying CTXs?
 - h. *Gambierdiscus* spp. physiology studies.
 - How long do CTXs stay in fish?
 - Does this vary by fish species?
 - i. Does seasonal variability in CFP occurrence exist?
 - Does this vary geographically?
 - Does this vary by fish species?
- ii) CTX and CFP testing.
 - a. Easier, cheaper, and faster ways for validating CTXs.
 - b. Investigate the accuracy of the exposure threshold (FDA guide of 0.1 ppb C-CTX-1)
 - Determine the actual CTX level that causes toxicity.
 - c. Identify the potential for contamination with regards to invasive lionfish venom toxins.
 - Learn more about the chemical makeup and identify the components of invasive lionfish toxins.
 - How does invasive lionfish venom affect CFP assays?
 - ⇒ Are false positives occurring and at what frequency?
 - Develop a standardized assay that takes invasive lionfish toxins into account.
- iii) Social science studies.

- a. Develop historical knowledge records (fishers, distributors, and restaurant owners) regarding CFP prevalence.
- b. In order to set legal precedence for CFP illness due to invasive lionfish, someone would need to 1) become ill with CFP after eating invasive lionfish, 2) sue the insurance company and the restaurant, and 3) a defense lawyer would need to take the case to court.
- c. Socioeconomic impacts of ciguatera.
- iv) Invasive lionfish harvesting
 - a. Identify priority sites.
 - b. Establish targeted removal values (# of invasive lionfish needed to be removed to maintain ecological impacts at X and socioeconomic impacts at Y).
 - c. Less intensive and more invasive lionfish specific harvesting methods and techniques.
 - Trap development.
 - Mass collection techniques.
 - Invasive lionfish attracting devices.

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