The Lionfish Project

A research project to investigate

The Impact of Invasive Lionfish on the Ecological Services of Parrotfishes and other Key Herbivores in Barbados

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Lionfish, *Pterios volitans.* Painting by H.A. Oxenford

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The Impact of Invasive Lionfish on the Ecological Services of Parrotfishes and other Key Herbivores in Barbados

1. INTRODUCTION

1.1 Project Background and Objectives

The Barbados Lionfish Project was undertaken by the Centre for Resource Management and Environmental Studies (CERMES) and the Department of Biological and Chemical Sciences of the University of the West Indies (UWI), in collaboration with partners including the Coastal Zone Management Unit (CZMU) and the Fisheries Division (FD) with funding from the Natural Heritage Department (NHD) of the Government of Barbados.

The project was conceived after the Biodiversity Working Group of the NHD drafted a 'Lionfish Response Plan for Barbados' (Brathwaite et al. 2011), in which lionfish were predicted to arrive imminently and begin to establish themselves in Barbados from late 2011. The Response Plan also highlighted the need for a collaborative approach among government institutions, the private sector and the University of the West Indies, with the latter primarily adopting a research role.

The project was thus initiated in recognition of a unique and urgent opportunity to rigorously assess the structure and function of parrotfish and surgeonfish communities in the reefs of Barbados before the establishment of the invasive lionfish. The project was principally designed to collect and archive 'pre-lionfish invasion' baseline data on the reef and reef fishery, thereby providing valuable opportunity to quantitatively examine the real impact of lionfish in the 'post-lionfish invasion' period. The baseline data are also expected to be helpful in drawing scientifically sound projections about the impacts of lionfish, thereby facilitating the development of marine policies seeking to mitigate these impacts. The key objectives were:

1. To quantify the importance of parrotfish and surgeonfish landings in the trap and spear fisheries before the arrival of lionfish.
2. To characterize parrotfish and surgeonfish communities on the reefs of Barbados before the establishment of the invasive lionfish.
3. To quantify the importance of algal grazing by parrotfishes and surgeonfishes before the arrival of lionfish.
4. To consider potential economic losses associated with changes in parrotfish and surgeonfish communities due to lionfish.
5. To inform national policy, and fisheries and reef management.

The project received funding to conduct the baseline research over a 2-year period, with 'pre-lionfish' baseline reef fisher and reef fish community surveys being conducted in Year 1, and manipulative grazing experiments conducted in Year 2. However, since the latter experiments were inconclusive, an alternative line of research was investigated with the funder's approval and additional support from UWI. This involved an additional two key objectives:

6. To document the arrival and spread of lionfish around the reefs of Barbados.
7. To determine the genetic identity (species and source population) of the Barbados lionfish population.

Here we report on the completed work of the Lionfish Project.

1.2 Key Aspects of the Indo-Pacific Lionfish Invasion in the Western Atlantic

1.2.1 The origin and spread of lionfishes

Invasions by non-native (alien) species are recognized as major threats to ecosystems, potentially causing dramatic effects on biodiversity and habitat composition (Mack et al. 2000) which in turn can have significant socioeconomic impacts on human populations. Whilst considerable damage has already been suffered in the Caribbean from numerous alien species invading terrestrial environments such as the giant African snail and pink hibiscus mealybug (see Kairo et al. 2003), there have been no major incidences of marine invasive species affecting Caribbean coral reefs until the recent invasion by the Indo-Pacific lionfishes (*Pterios volitans* and *P. miles*) (Schofield 2010). This lionfish invasion is unprecedented, not only because it is the first case of non-native marine fishes invading and become established in the region, but because of the remarkable speed with which they have been able to spread (Figure 1), despite significant natural population connectivity barriers among sub-regional coral reef populations (e.g. Cowen et al. 2006). Originating from aquarium releases in Florida in the late 1980s and early 1990s (Freshwater et al. 2009), the non-native population comprising two species of lionfish spread up the USA east coast, across to Bermuda and ultimately to the Bahamas by 2004 (Figure 1). Subsequently, one species (*Pterios volitans*) crossed into the Caribbean basin and spread rapidly, invading islands in the northern Caribbean, through Central American reefs and along the Caribbean coast of South America reaching the eastern Caribbean islands from 2010, including Barbados in late 2011 and Tobago, the last island to be invaded, in 2012 (Figure 1, USGS-NAS; http://nas.er.usgs.gov/).

Lionfishes, especially *P. volitans*, have been exceptionally successful at invading the western Atlantic, having significant dispersal capabilities and adapting quickly to alien environments. They have low mortality rates, having few if any native predators or parasites, and have voracious appetites, growing fast and maturing within their first year of life (Morris et al. 2009). Once mature, they produce free-floating gelatinous egg masses containing thousands of eggs every few days, which hatch into planktonic larvae with a free floating 20-35 day pelagic phase (Ahrenholz and Morris 2010).

1.2.2 The lionfish threat

Lionfishes are considered to represent a significant ecological threat to the coral-reef ecosystems of the Caribbean and hence a substantial economic threat to the countries whose economies rely heavily on healthy reefs, such as Barbados. Their rapid reproduction and low mortality rates mean that lionfish are capable of quickly overpopulating reefs. This, combined with their aggressive behaviour and voracious predation rates is likely to have significant ecological effects through consumption and displacement of native prey species and potential competitors (Albins and Hixon 2008, Green et al. 2012). This could change the species composition on reefs, thereby affecting the value of reef fishers' catches or preventing recovery of overexploited species under management. Furthermore, reef food webs may be significantly affected, resulting in the loss of trophic balance in the reef community. This could in turn lead to ecosystem degradation through removal of keystone species or functional groups.

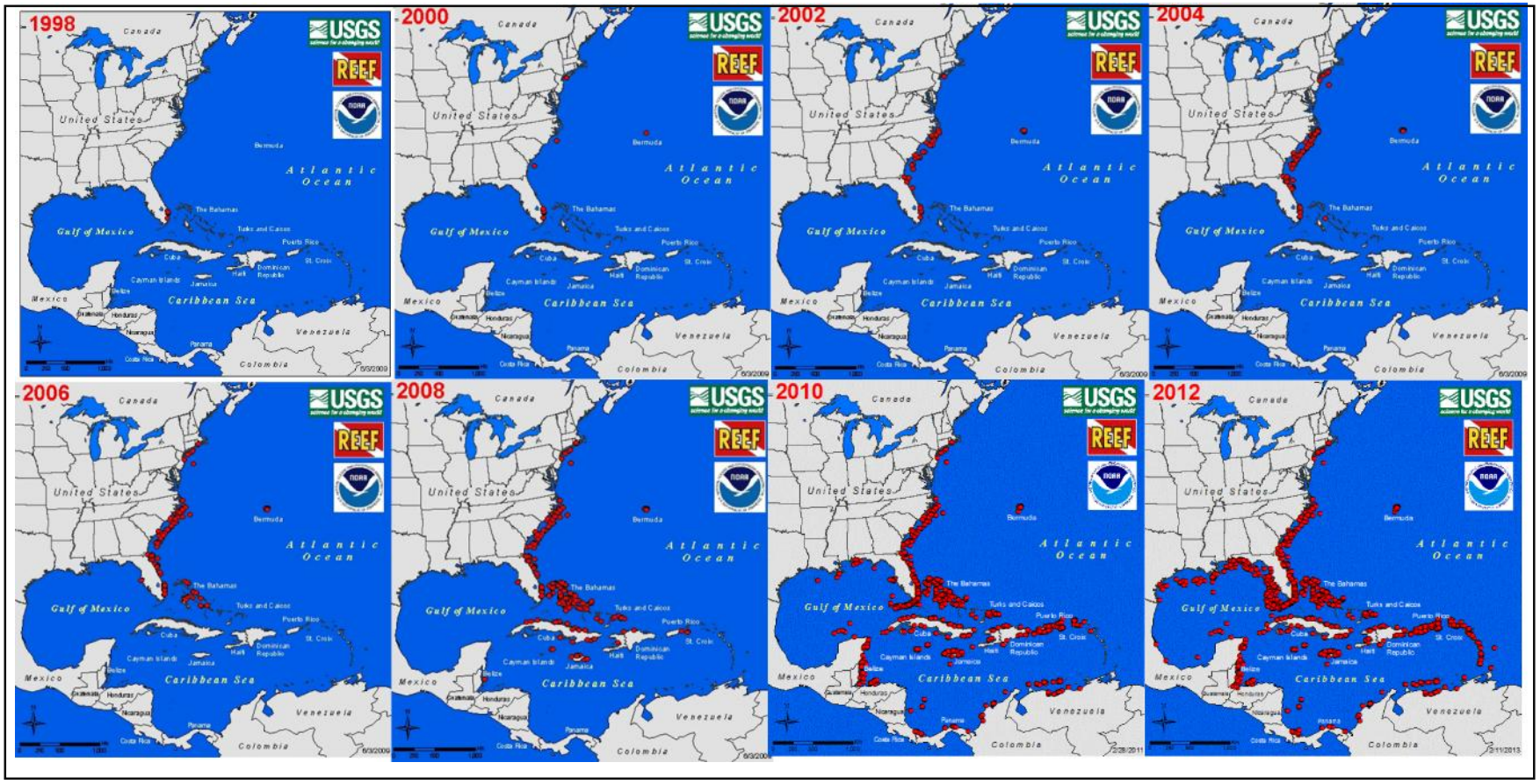

Figure 1. Progression of the lionfish invasion in the western Atlantic from 1998-2012 as indicated by lionfish sightings reported to the US Geological Survey Non-indigenous Aquatic Species (USGS-NAS) database (http://nas.er.usgs.gov/).

Of particular concern are the parrotfishes and other key herbivore populations, such as surgeonfishes, which provide two main types of services to humans. First, they graze large amounts of algae on the reefs, playing a key role in maintaining healthy and attractive reefs for recreational divers and dive-operators, an industry that generates millions of dollars annually in Barbados (Gill 2014). Second, they are among the most important target families in the nearshore fisheries of Barbados, providing important income to fishers and fish protein to Barbadians, in small scale fisheries that are estimated to generate several million dollars annually in landings revenues alone (Maraj et al. 2011, Schuhmann et al. 2011, Simpson et al. *in press*). These two important services of parrotfishes and surgeonfishes could be compromised once lionfish become established in Barbados, since they are capable of consuming large numbers of juvenile parrotfishes and other significant herbivores. Lesser and Slattery (2011) suggest that lionfish could reduce herbivore populations to the extent that a phase shift to an algal dominated coral community occurs. The ultimate impact of this scenario would be the loss of vital ecosystem services provided by reefs, including those critical to Barbados (e.g. provision of food and livelihood security to reef fishers and the wider community; aesthetic quality and value to the watersports tourism sector; provision of white sand beaches and coastal protection).

Moreover, lionfish have venomous spines that can pierce through the human skin and cause envenomation, which constitutes a serious health threat to humans, requiring immediate treatment, and therefore posing an additional social burden, as the invasion has spread across the region. Badillo et al. (2012) reported that in humans, lionfish venom has been found to have many effects ranging from mild reactions, including swelling, dizziness, local numbness and sweatiness to rare, but more serious symptoms including nausea, vomiting, extreme abdominal pain, temporary paralysis of the limbs, loss of consciousness, heart complications and even death.

2. PRE-LIONFISH BASELINE INFORMATION ON THE REEF FISH FISHERY

2.1 Reef Fisher Catch and Effort Surveys

Surveys of reef fishers at the main landing sites on the west (Pile Bay) and south (Oistins) coasts were conducted during the winter (cooler water / pelagic fishing season) and the summer (warmer water / pelagic fishing off-season) during the first year of the project to determine baseline catch and effort data before the potential impacts of lionfish on the reef fisher catches.

The winter survey was conducted between 26 Jan – 8 March 2012 and the summer survey took place from 19 August – 23 September 2012. During these surveys, the fishing effort and catches of the main reef fishers (trap and spear fishers) were monitored over a one month period in order to assess species composition and size of individuals landed for the baseline dataset.

For the first survey, nine trap fishers and seven spear fishers were monitored, while seven trap fishers and nine spear fishers were monitored during the second survey.

2.2 Catch Composition

2.2.1 Taxonomic groups

The catches of both spear fishers and trap fishers were multispecies with at total of 58 species from 19 families being recorded overall (spear fishers 42 spp. from 16 families; trap fishers 48 spp. from 16 families, Table 1 and Appendix 1).

Over 2,000 individual fish were recorded (821 from spear fishers, 1,375 from trap fishers, Appendix 1). The top ten fish families (ranked based on frequency of occurrence in recorded catches across both gears combined; Table 1) are shown in Figure 2 for trap fishers and spear fishers for each survey. Both types of fishers had very similar catch compositions in both surveys, indicating that there was minimal seasonal affect on availability or choice of target species. As such data were combined across the two surveys to compare between fisher types (Figure 3).

The key herbivore families (parrotfishes and surgeonfishes) made up more than half the catch of both spear and trap fishers (Figures 2 and 3). The parrotfish family was the most important, accounting for half or just under half of the overall catch for each gear type, whilst the surgeonfishes contributed 6% to spear fisher catches and 9% to trap fisher catches overall (Figures 2 and 3).

Interestingly, spear fishers, who are able to select the individuals caught, appear to catch more than three times the proportion of snappers caught by trap fishers and also target barracudas which are not taken by traps. On the other hand, traps, considered a passive gear, are catching considerably more goatfish and twice the proportion of grunts and squirrelfishes that are taken by spear fishers (Figure 3).

Table 1. List of fish families and number of individuals recorded in the catches of spear and trap fishers in Barbados in 2012 during the winter (Jan/Feb) and summer (Sep/Oct) fishing periods.

Family (common name)	Spear		Spear Total	Trap		Trap Total	Grand Total	Abundance Rank
	Survey 1 (Jan/Feb)	Survey 2 (Sep/Oct)		Survey 1 (Jan/Feb)	Survey 2 (Sep/Oct)			
Scaridae (parrotfishes)	222	184	406	322	303	625	1031	1
Haemulidae (grunts)	5	37	42	88	53	141	183	2
Carangidae (jacks)	26	36	62	68	50	118	180	3
Acanthuridae (surgeonfishes)	11	38	49	80	41	121	170	4
Holocentridae (squirrelfishes)	10	26	36	59	63	122	158	5
Lutjanidae (snappers)	31	50	81	22	26	48	129	6
Mullidae (goatfishes)	0	2	2	39	53	92	94	7
Serranidae (groupers/hinds)	31	9	40	18	22	40	80	8
Monacanthidae (filefishes)	9	11	20	29	11	40	60	9
Sphyraenidae (barracudas)	30	2	32	0	0	0	32	10
Balistidae (triggerfishes)	3	14	17	1	7	8	25	11
Labridae (wrasses)	9	10	19	0	4	4	23	12
Kyphosidae (sea chubs)	6	4	10	1	3	4	14	13
Pomacentridae (damselfishes)	0	0	0	6	0	6	6	14
Ostraciidae (boxfishes)	0	1	1	1	1	2	3	15
Scombridae (tunas/mackerels)	3	0	3	0	0	0	3	16
Chaetodontidae (butterflyfishes)	0	0	0	2	0	2	2	17
Pomacanthidae (angelfishes)	0	0	0	1	0	1	1	18
Sparidae (porgies)	0	1	1	0	0	0	1	19
Total families	13	15	16	15	13	16	19	

2.2.2 Mean size of fish

Although there is considerable overlap in the species taken by each gear type, spear fishers, who are selecting their catch, land larger individual fish on average than trap fishers (Appendix 2: spear mean fish size: 26.7 cm FL, trap mean fish size: 19.4 cm FL). This result was consistent across all species groups and both surveys (with the exception of filefishes in the second survey, Figure 4) and was highly significant (ANOVA comparing overall mean size between gears: n = 821, 1374, df = 1, F = 808.45, $p<0.001$).

The difference in mean size of the key herbivores landed by spear and trap fishers is highlighted in Figure 5 and was also highly significant, with spear fishers catching much larger parrotfishes (mean size: 26.2 ± 3.9 cm FL vs 19.3 ± 2.3 cm FL) and surgeonfishes (mean size: 21.2 ± 2.5 cm FL vs 15.5 ± 2.4 cm FL) than trap fishers (ANOVA: for parrotfishes n = 406, 625, df = 1, F = 1259.23, $p < 0.001$; for surgeonfishes n = 49, 121, df = 1, F = 186.26, $p < 0.001$).

2.1 Catch per Unit Effort

2.1.1 Trap fishers

Fishing effort information was collected for 63 trap fishing trips and total catch weight was recorded for 24 of these trips over both summer and winter surveys. Trap fishers used standard rectangular traps with a wooden stick frame, 1¼" mesh wire and two funnels. Most traps measured approximately 7' x 5' x 2' or 7' x 4' x 2', were deployed and hauled by hand and were left to soak (passively fishing) for between 3-21 days (mean: 6 days, mode: 7 days). All trap fishers used a boat (Figure 6) and fished alone or with up to four others (mean fishers per boat trip was 2). Fishing trips took from 1½ to 6½ hours, although most were 2½ - 3 hours long (mean: 2.6 hr), and between 1-15 traps were hauled per trip (mean: 7.2 traps per trip).

Catch per fishing trip ranged from 7.7 – 52.2 kg of reef fish, with a mean of 21.7 kg, worth Bds$239. This represents a mean catch per trap of just 3.1 kg reef fish (range: 1.0 – 8.7 kg) or a mean catch per fisher per trip of 10.2 kg (range: 3.6 – 32.2 kg) with a value of Bds$112.36

2.1.2 Spear fishers

Fishing effort information was collected from 32 spear fishing trips and total catch weight was recorded for 12 of these fishing trips over both summer and winter surveys. All recorded spear fishing trips were conducted by boat with between 1-6 fishers onboard (mean fisher per boat trip was 2.6). Spear fishing trips took from 1½ to 9½ hours (mean: 4.7 hr).

Catch per fishing trip ranged from 15 – 53.1 kg of reef fish, with a mean of 16.4 kg worth approximately Bds$181. This represents a mean catch per fisher per trip of 5.6 kg (range: 3.6 – 29.2 kg) with an approximate value of Bds$62.35.

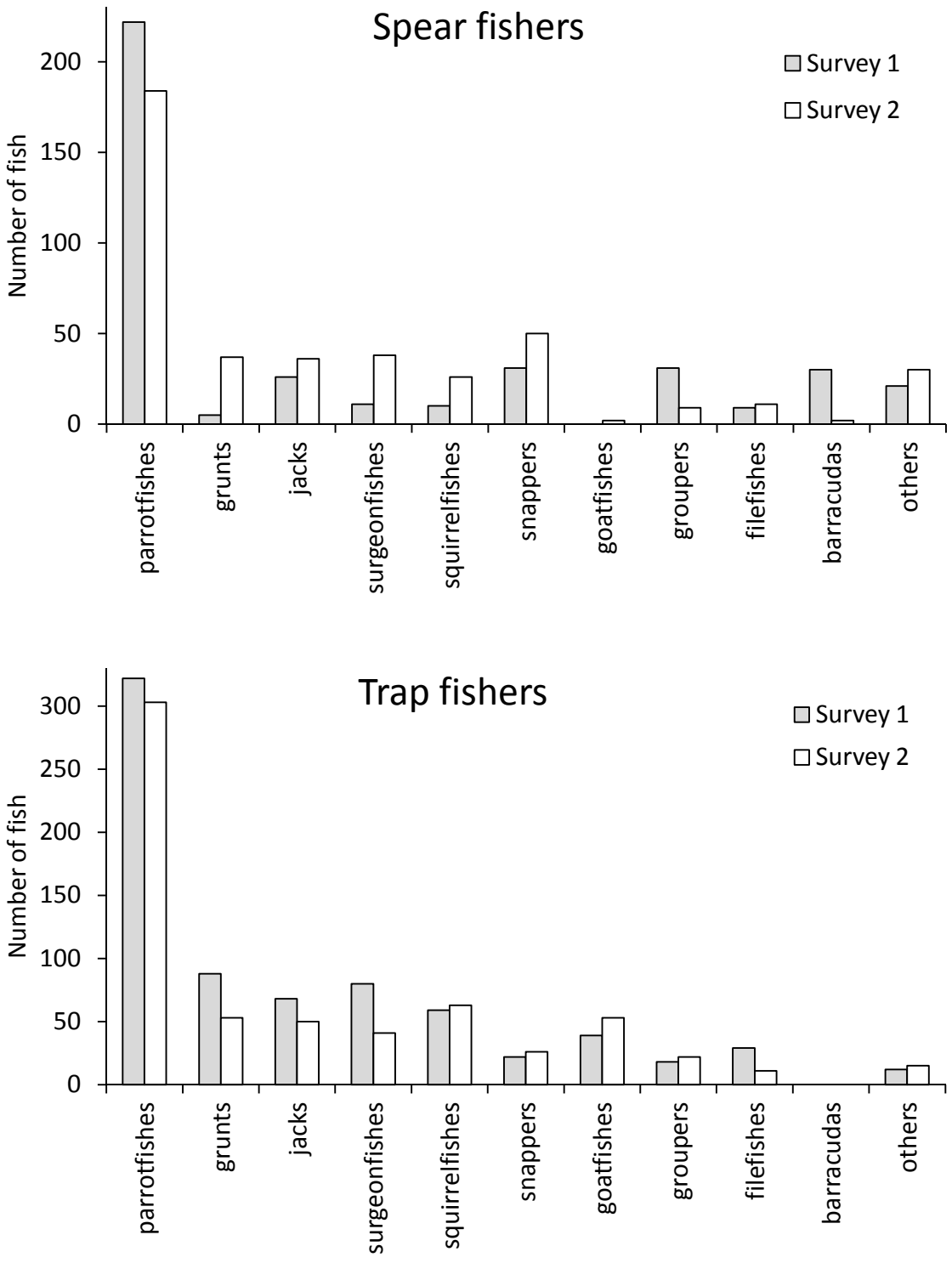

Figure 2. Taxonomic composition of catches (as number of fish) shown by main families for spear and trap fishers surveyed in Barbados in 2012 during Jan/Mar (Survey 1) and Aug/Sep (Survey 2). Fish families are ordered according to their overall abundance rank, from most to least important.

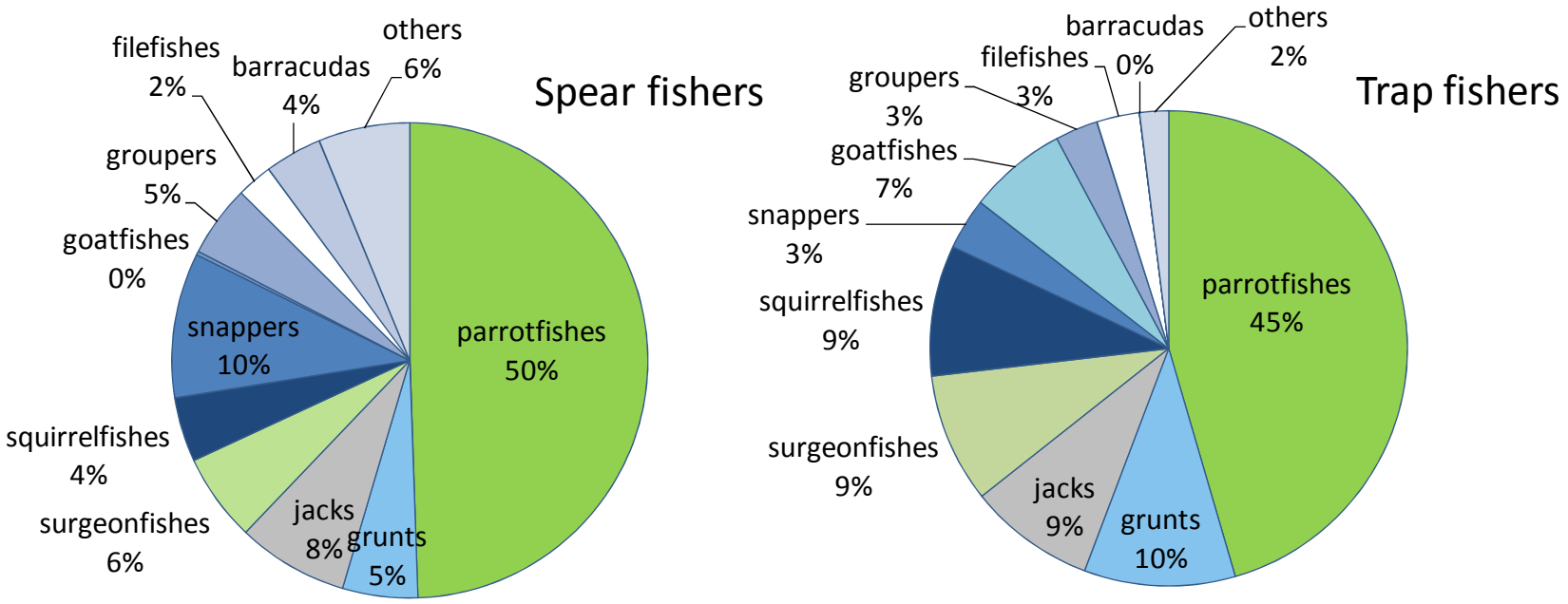

Figure 3. Overall taxonomic composition of catches (as number of fish) shown for spear and trap fishers surveyed in Jan/Mar (Survey 1) and Aug/Sep (Survey 2) 2012 shown by main fish families combined across both surveys.

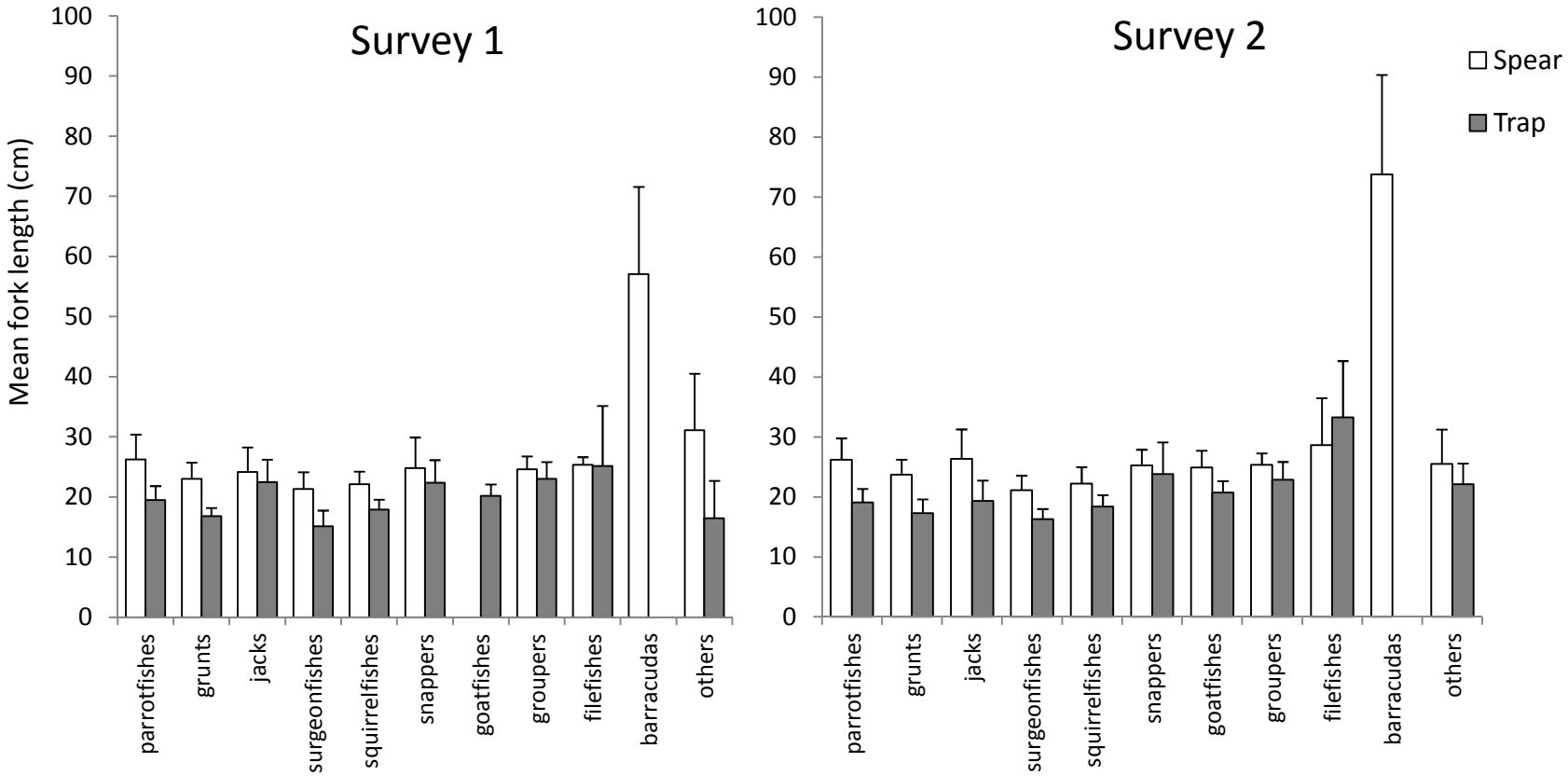

Figure 4. Comparison of mean individual fish size caught by trap and spear fishers in Barbados, shown by main fish families arranged left to right in order of importance (based on overall numbers caught). Data from fishers in Pile Bay and Oistins are pooled. Full data set is given in Appendix 2.

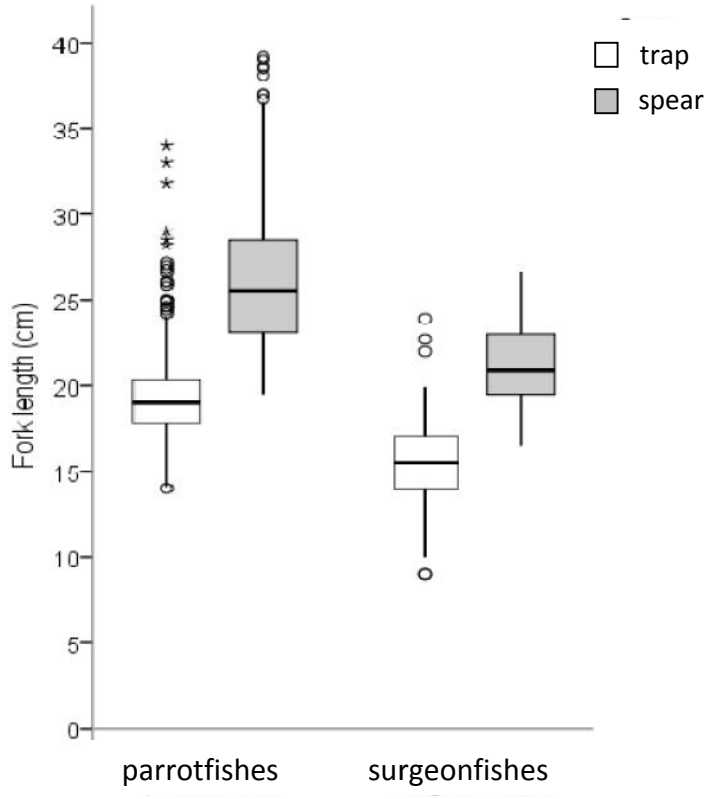

Figure 5. Box and whisker plot comparing the size of the key herbivores taken by spear and trap fishers. Data are combined across Pile Bay and Oistins, and across both surveys. Boxes indicate include 50% of the fork length observations for each fish family and gear type.

Figure 6. Fish vendors collecting reef fish catch from trap fishers at the landing beach in Pile Bay. The typical small 'moses' fishing boats and a fish trap can be seen pulled up on the beach

3. PRE-LIONFISH BASELINE INFORMATION ON THE REEF FISH COMMUNITY

3.1 Fish Community Surveys

Surveys of fish size and abundance on ten reefs (3 deep and 7 shallow) located along the west and south coasts of Barbados (Figure 7) were conducted every four months over the first year of the project to provide baseline information on the status of fish communities before the spread of lionfish, especially the abundance of key herbivores (parrotfishes, surgeonfishes and the *Diadema* sea urchin).

Survey 1 took place in Jan/Feb 2012, Survey 2 in May/Jun 2012, and the final survey in Oct 2012. The survey protocol is described in detail in Appendix 3. In summary, ten belt transects, measuring 30 x 2 m for large mobile species and 30 x 1 m for the smaller less mobile species and urchins, were surveyed at each reef site by a team of SCUBA divers. Fishes were recorded separately by species and size was estimated to the nearest cm fork length (FL), whilst *Diadema* urchins were simply recorded by number. Divers were specifically trained to estimate fish size accurately (to the nearest cm), using fish models (Figure 8).

Overall, data were collected for 80 fish species (65 highly mobile species and 15 slow or cryptic species) and are available from the authors as archived data in excel. However, only data for the focal families – the key herbivores (8 parrotfish species, 3 surgeonfish species and *Diadema* urchins) are presented here. No lionfish were encountered on any of the transects during any of the surveys, although one was seen in the last survey at Accra Bank. This confirms that these results represent the status of reef fish communities in Barbados immediately prior to the establishment of a significant lionfish population.

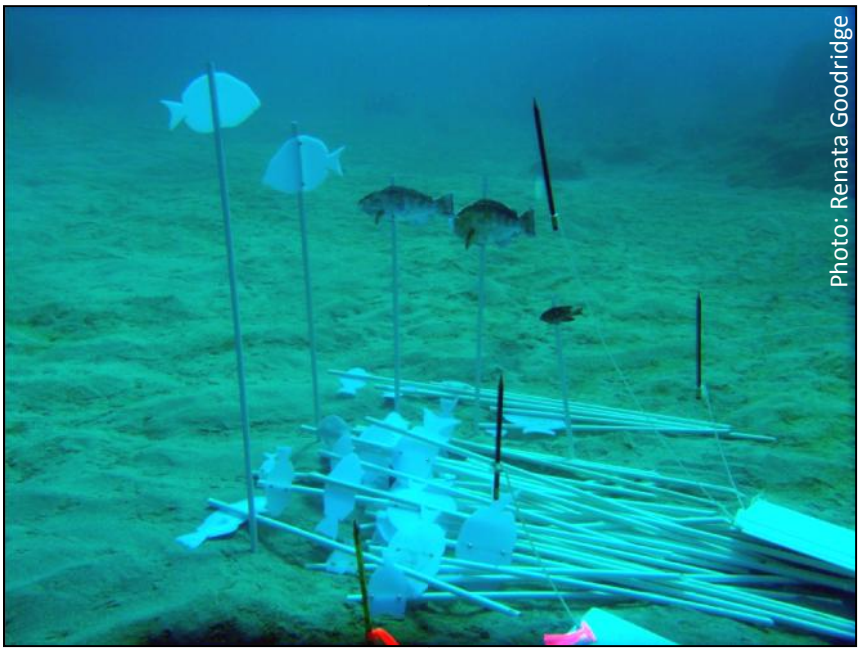

Figure 8. Fish models and recording slates used in diver training to accurately estimate fish size underwater.

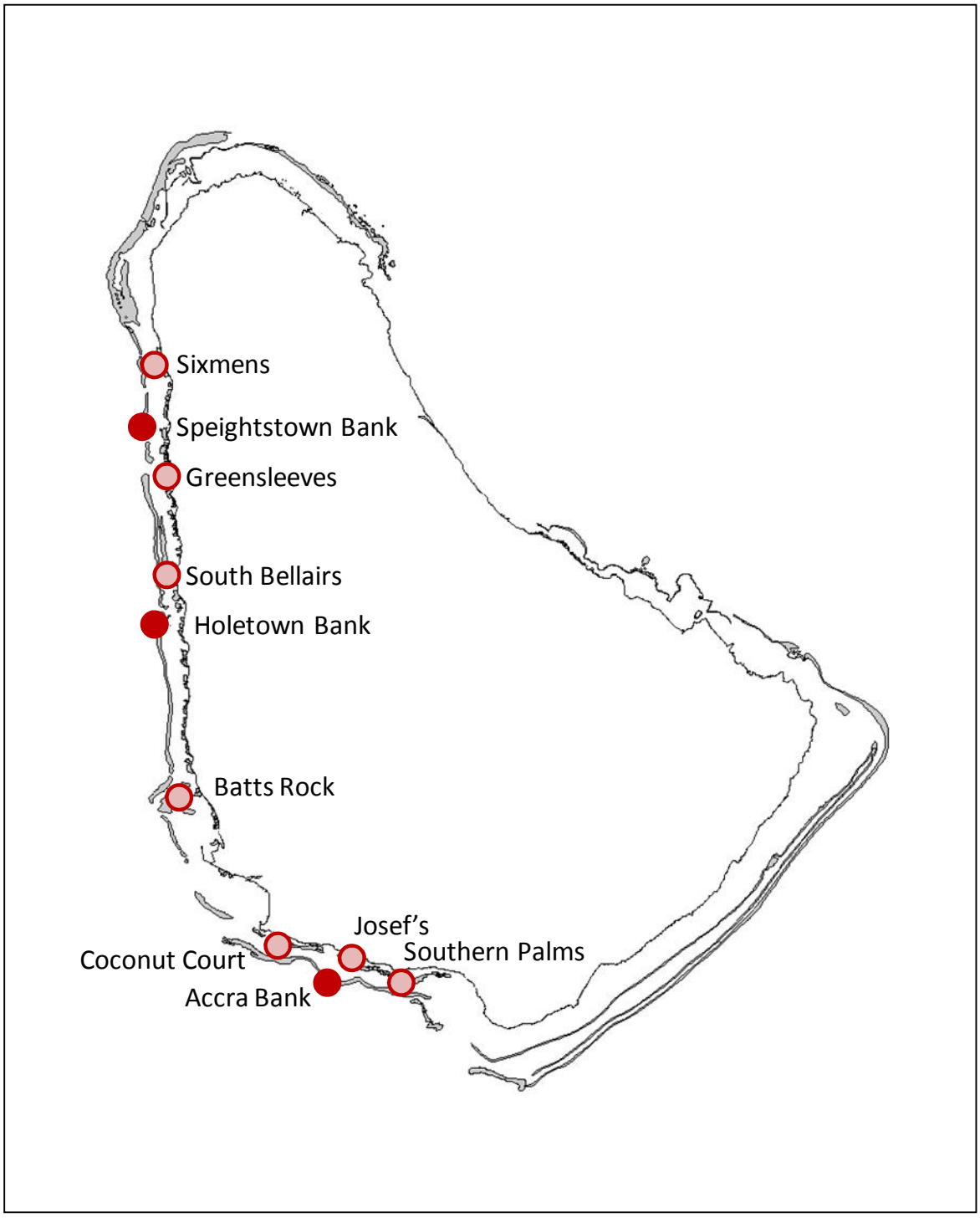

Figure 7. Map of the coral reefs of Barbados showing the locations of the ten survey sites for fish community monitoring. Solid red circles indicate deep reefs (> 15 m); pink circles indicate shallow reefs (<10 m).

3.2 Fish Density

Density of surgeonfishes and parrotfishes at each of the ten monitored reefs are shown in Table 2 for each of the three surveys.

Table 2. Density of key herbivorous fish families across the ten monitored reefs shown as total number of individuals per 600 m^2 for each of the three surveys. Sites arranged from north to south.

Coast	Reef site	Survey					
		Surgeonfishes			Parrotfishes		
		1 (Jan/Feb)	2 (May/Jun)	3 (Oct)	1 (Jan/Feb)	2 (May/Jun)	3 (Oct)
West	Speightstown Bank	12	6	8	54	72	85
	Sixmens	11	27	9	9	12	17
	Greensleeves	10	9	8	26	21	39
	South Bellairs	182	20	233	34	55	34
	Holetown Bank	17	24	17	60	81	70
	Batts Rock	4	2	12	7	9	11
South	Coconut Court	46	40	32	47	30	53
	Accra Bank	8	4	6	38	39	65
	Josef's	21	15	8	48	19	52
	Southern palms	15	25	10	30	36	37

There is considerable variation in the density of both families across the different reefs, which held true across all three surveys (Table 2), suggesting that differences among reefs in the relative density of the key herbivore fish families are consistent over time and thus likely reflect differences in habitat and/or levels of fishing pressure among the different reef sites. For example, on the west coast surgeonfishes where relatively scarce at Batts Rock, a heavily fished site, and had the highest densities at South Bellairs and Holetown Bank, both sites within the Folkestone Marine Reserve. Large grazing schools of surgeonfishes are common at these sites (Figure 9). On the south coast, the highest densities were consistently recorded at Coconut Court (Table 2, Figure 10). Parrotfishes on the west coast were also consistently rare at Batts Rock and had the highest densities at Speightstown Bank and in the reserve at Holetown Bank and South Bellairs across all three surveys (Table 2, Figure 10). Parrotfishes were relatively common on the south coast reefs (Table 2, Figure 10).

3.3 Fish Size

Individual mean size also shows variation among reefs for both families, and some consistency between surveys (Table 3). Overall, the smallest surgeonfishes on average were seen at the heavily fished Batts Rock site, although this was not the case with parrotfishes (Figure 11). However, too few fish herbivores were observed at this site (Table 2) so that size estimates at Batts Rock are likely to be overly imprecise and warrant caution. The smallest mean sized

parrotfishes were observed on the west coast at Josef's and Sixmens, whilst the largest were seen at the protected (no take) South Bellairs site (Figure 11).

Figure 9. Large school of grazing surgeonfishes (predominantly blue tangs with a few ocean surgeonfish) typical of South Bellairs reef.

Table 3. Mean size (mm FL) of key herbivorous fish families across the ten monitored reefs for each of the three surveys. Sites arranged from north to south.

		Survey					
		Surgeonfishes			Parrotfishes		
Coast	Reef site	1 (Jan/Feb)	2 (May/Jun)	3 (Oct)	1 (Jan/Feb)	2 (May/Jun)	3 (Oct)
	Speightstown Bank	13.7	14.3	14.5	16.0	15.8	14.8
	Sixmens	19.7	13.4	12.0	18.6	12.8	11.9
	Greensleeves	10.7	16.4	10.9	18.6	16.9	12.6
	South Bellairs	15.9	16.4	12.5	21.6	21.4	15.9
	Holetown Bank	15.6	14.1	13.8	17.5	16.5	16.2
West	Batts Rock	11.0	10.0	6.8	18.4	19.6	12.1
	Coconut Court	14.8	14.5	15.3	15.2	16.3	15.5
	Accra Bank	15.1	12.0	15.7	19.8	17.3	16.2
	Josef's	13.2	13.8	9.9	15.4	13.4	14.1
South	Southern palms	15.5	14.2	18.2	14.6	15.3	15.8

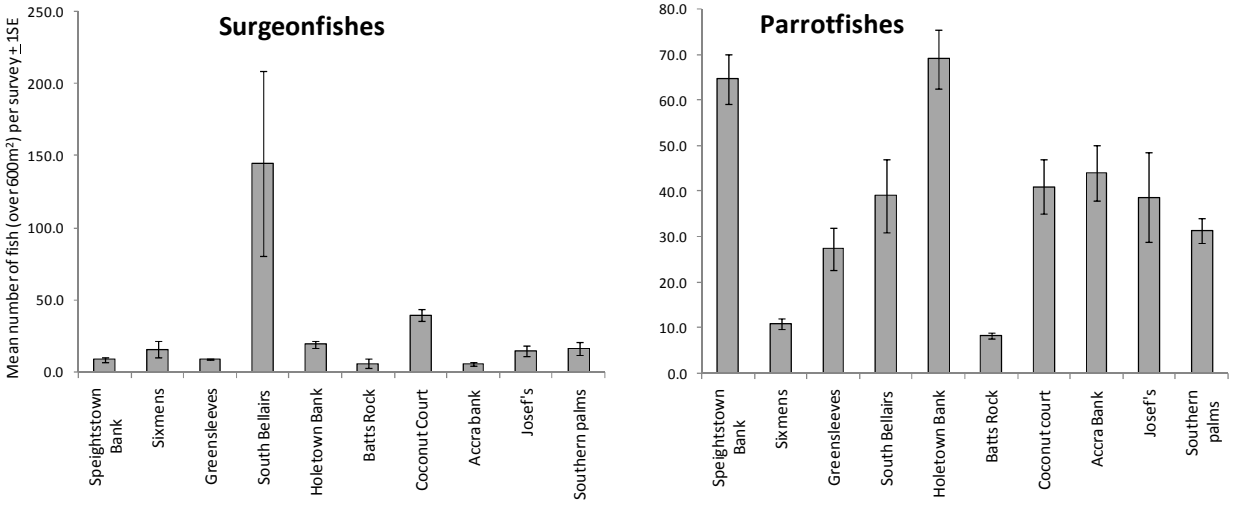

Figure 10. Overall mean abundance of fish (per 600 m^2) in the key herbivorous families observed at each of the ten monitored reefs, across all three surveys. Sites arranged from north to south.

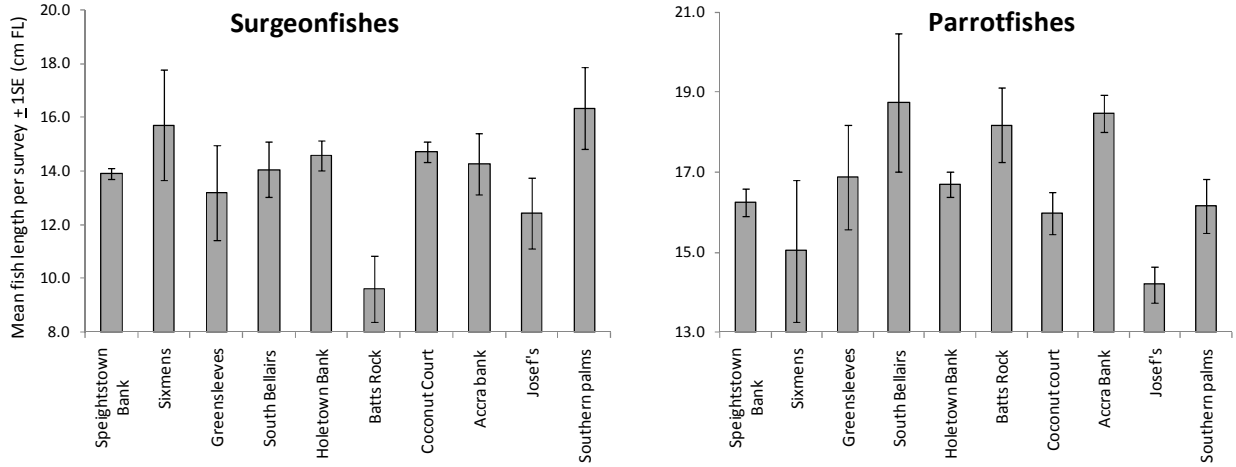

Figure 11. Overall mean size of fish (cm FL) in the key herbivorous families observed at each of the ten monitored reefs, across all three surveys. Sites arranged from north to south.

3.4 Urchin density

The density of *Diadema* urchins is given in Table 4 and shows significant variation among reefs and between coasts, and high consistency among surveys with the exception of the Batts Rock site. No urchins were found on any of the deep bank reefs during any of the surveys. The west coast shallow reefs generally had very low density of urchins compared with the shallow reefs of the south coast.

Table 4. Density of *Diadema antillarum* urchins on the ten monitored reefs, shown as number per 300m^2 for each of the three surveys. Sites arranged from north to south.

Coast	Reef site	Survey 1 (Jan/Feb)	Survey 2 (May/Jun)	Survey 3 (Oct)	Overall mean
West	Speightstown Bank	0	0	0	0
	Sixmens	2	6	0	2.7
	Greensleeves	2	0	0	0.7
	South Bellairs	0	3	1	1.3
	Holetown Bank	0	0	0	0
	Batts Rock	3	1	15	6.3
South	Coconut court	35	58	85	59.3
	Accra Bank	0	0	0	0
	Josef's	32	43	15	30.0
	Southern palms	19	25	27	23.7

4. PRE-LIONFISH BASELINE LEVEL OF ALGAL GRAZING BY REEF HERBIVORES

4.1 Introduction

Through their algal grazing activity, parrotfishes and surgeonfishes play a key role in keeping macroalgae in check on coral reefs, thus potentially facilitating coral recruitment, survivorship and/or growth (Mumby 2006, Mumby et al. 2006, Burkepile and Hay 2008, Bellwood et al 2012). How much algae these fish herbivores remove from the reefs of Barbados has never been rigorously quantified and will depend, to a large extent, on how abundant and large these fishes are. It is important to quantify current algal removal rates by reef fish herbivores in order to predict the impact that changes in their abundance and size-structure, potentially due to lionfish predation, will have on the reef benthos.

The purpose of this investigation was to measure the 'pre-lionfish' level of algal grazing by herbivores on a typical shallow reef in Barbados, so as to provide baseline information on the grazing function of reef herbivores before the impact of lionfish on the herbivorous community.

4.2 Materials and Methods

We attempted to quantify the amount of algae consumed by large fish herbivores using Grazing Exclusion Cage Units (GECUs). This involved measuring natural algal growth rates on clean/clear substrates from which large fish herbivores were excluded using cages (grazer exclusion treatment) and comparing these rates with those on clean/clear substrates where fish herbivores were allowed access (control treatment).

In addition to, and concurrent with, the grazer exclusion experiment, we conducted underwater fish surveys (to quantify parrotfish and surgeon fish community structure) and benthic surveys (to quantify algal percent cover and diversity) at the site by setting (2 x 30 m) permanent transects which were surveyed periodically.

4.2.1 Grazing Exclusion Cage Units

A total of eight GECUs were constructed. Each GECU comprised a 50 x 50 x 30 cm 1¼" wire mesh cage with a pvc pipe frame (one side of which could be opened to retrieve tiles) and a 50 x 50 cm open frame supporting the same wire mesh. These were fastened together with cable ties and supported horizontally on two lengths of re-bar attached to a mooring. The mooring was constructed from a cement-filled vehicle tyre. Nine clean/clear ceramic tiles (shiny side uppermost) were attached with cable ties onto the floor of the cage (grazer exclusion treatment), and a further nine were attached onto the adjacent open frame (control treatment) (Figure 11).

Figure 11. Images of two of the grazing exclusion cage units (GECUs) deployed within the Batts Rock shallow patch reef in July 2013. Right image shows the growth of turf algae on tiles within and outside the exclusion cage after 14 days.

4.2.2 Experimental Design

The GECUs were set out in two rows 30 m apart within the Batts Rock patch reef area. The cages were checked bi-weekly and the tiles inside and outside the cages were photographed to document the algal growth. A subsample of tiles was also collected at weekly intervals to quantitatively measure algal growth and diversity in the laboratory.

4.3 Outcomes

Unfortunately, this experiment had to be abandoned approximately two months after deployment of the cages due to an unexpected and uncontrolled, but highly influential, factor. Soon after deployment of the units, adult three-spot damselfish (*Stegastes planifrons*) and longfin damselfish (*S. diancaeus*) quickly expanded or moved their territories to include the GECUs. Personal underwater observations showed that the consistent aggressive behaviour of the damselfishes towards large fish herbivores that approached the GECUs interfered strongly with the experimental treatments and precluded any meaningful comparison. The high density and widespread distribution of damselfishes in the reef meant that moving the GECUs to different locations could not solve this problem.

5. ARRIVAL, SPREAD, BIOLOGICAL CHARACTERISTICS AND GENETIC IDENTITY OF LIONFISH IN BARBADOS

5.1 Public Education and Information

One of the first steps to ensure full stakeholder participation in the reporting of lionfish arrivals in Barbados was to establish a multifaceted public education campaign. The components of this educational campaign are given below and were conducted under the leadership of the Project's Government institutional partners, the Coastal Zone Management Unit (CZMU) and the Fisheries Division.

5.1.1 Local media

Project researchers and partners informed local radio and newspapers, recreational dive shops and fishers of the iminent arrival of lionfish in Barbados (see Appendix 4). The research project was featured in the March 2012 issue of the UWI, Cave Hill campus quarterly magazine 'Chill'.

5.1.2 Telephone hotline

The project launched a 24 hour telephone hotline (824-8361) in December 2011 to handle reports of lionfish sightings and answer questions from the general public. This remains active and the responsibility for the hotline has now been assumed by the CZMU.

5.1.3 Webpages

A Facebook page [https://www.facebook.com/pages/Lionfish-Barbados-hotline-246-824-8361/252570021471424] was set up as a means of information exchange and communication with the general public and the media. This also remains very active and has continued to inform not only the local population, but media houses, researchers and the general public from across the region. This site is now maintained largely by the CZMU. The CERMES website and the CZMU website also have additional information and links to this facebook page.

5.1.4 Workshops

A mini-workshop on lionfish and safe handling practises was put on for fishers as part of the Fisher's Forum (June 27, 2012) during the national Fishermen's Week (Figure 12). Furthermore, the CZMU and Fisheries Division (FD) partnered in an initiative to train staff of the National Conservation Commission, lifeguards in particular, on lionfish handling, first aid and general information.

5.1.5 Information brochures

The project partners have produced several information leaflets which have been widely distributed among dive operators, fishers, hoteliers and made available to the general pubic

during AgroFest 2012 and 2013 and through the partner websites and the Project facebook page (see Appendices 5 & 6).

Figure 12. Fisher workshop on safe handling of lionfish, June 2012.

5.2 First Lionfish Arrivals

5.2.1 Data collection

All reported sightings were recorded on a standard reporting form (Appendix 7) and were subsequently transferred to the shared project database (Appendix 8).

5.2.2 Rate of sightings

The first confirmed sighting of a lionfish in Barbados was on November 24, 2011. This specimen was captured by a recreational diver and handed over to project staff. Over the following nine months, confirmed reports of new arrivals continued to trickle in slowly, with a total of 6 specimens being reported after six months (by 22 May 2012), five by recreational dive operators and one by a trap fisher. From August 2012, there was a marked increase in the rate of reported sightings (Figure 13) with the total being 54 specimens after one year (up to 15 November 2012) (Appendix 8).

Most of the lionfish specimens were seen and/or captured and reported by recreational divers (60%) and spearfishers (25%). A further 9% were taken by trap fishers, whilst the remaining 6% were reported by a variety of other marine stakeholders (Appendix 8).

A map showing the sighting locations of these early arrivals is given in Figure 14.

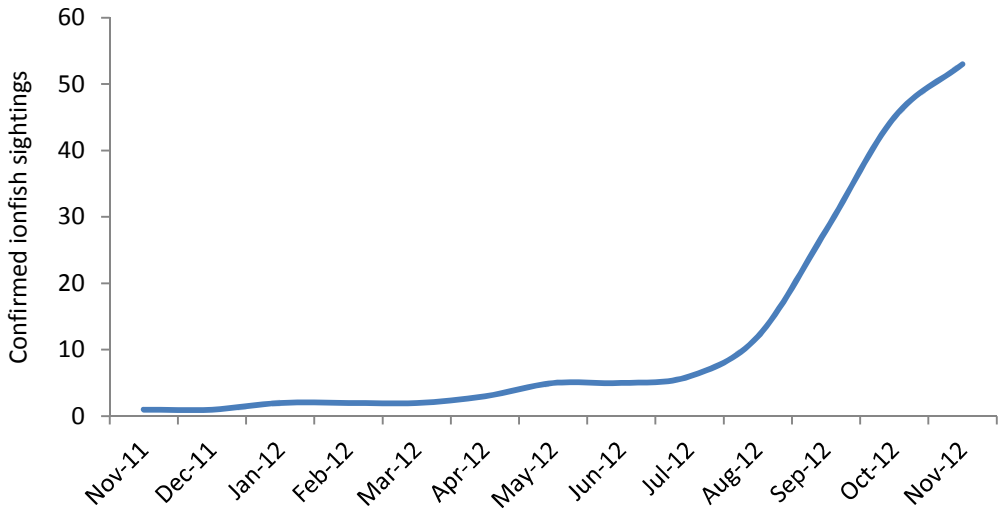

Figure 13. Record of lionfish arrivals in Barbados, shown as cumulative number of confirmed lionfish sightings per month over the first year. First sighting was on 24 November 2011.

5.2.3 Spread of early invaders

The first reported lionfish was from the northern section of the west coast. The next four reports indicated a gradual spread down the sheltered leeward west coast and by the November 15th 2012, lionfish had been found along the entire west coast, the western part of the south coast and one had also been captured off the exposed windward east coast (Figure 14). However, there had been no reports from the southeast coast up to the end of the first year.

Over the second year, official reported sightings to The Lionfish Project via the hotline declined as resource users became accustomed to seeing and catching the invasive fish. Anecdotal reports and observations indicated frequent sightings, but the lionfish were either killed and left on the reef by divers and fishers, or were retained for consumption. Lionfish can now be found around the entire island (see Section 6.2 below).

5.2.4 Misidentifications

Over the first seven months there were a large number of reports by persons who were misidentifying the native stonefish (‘sculpin’), flying gurnard (‘batfish’) and sargassum frogfish as lionfish, prompting the production of a second informative brochure (Appendix 6) and photographs of all these species being placed on the Project’s lionfish facebook page.

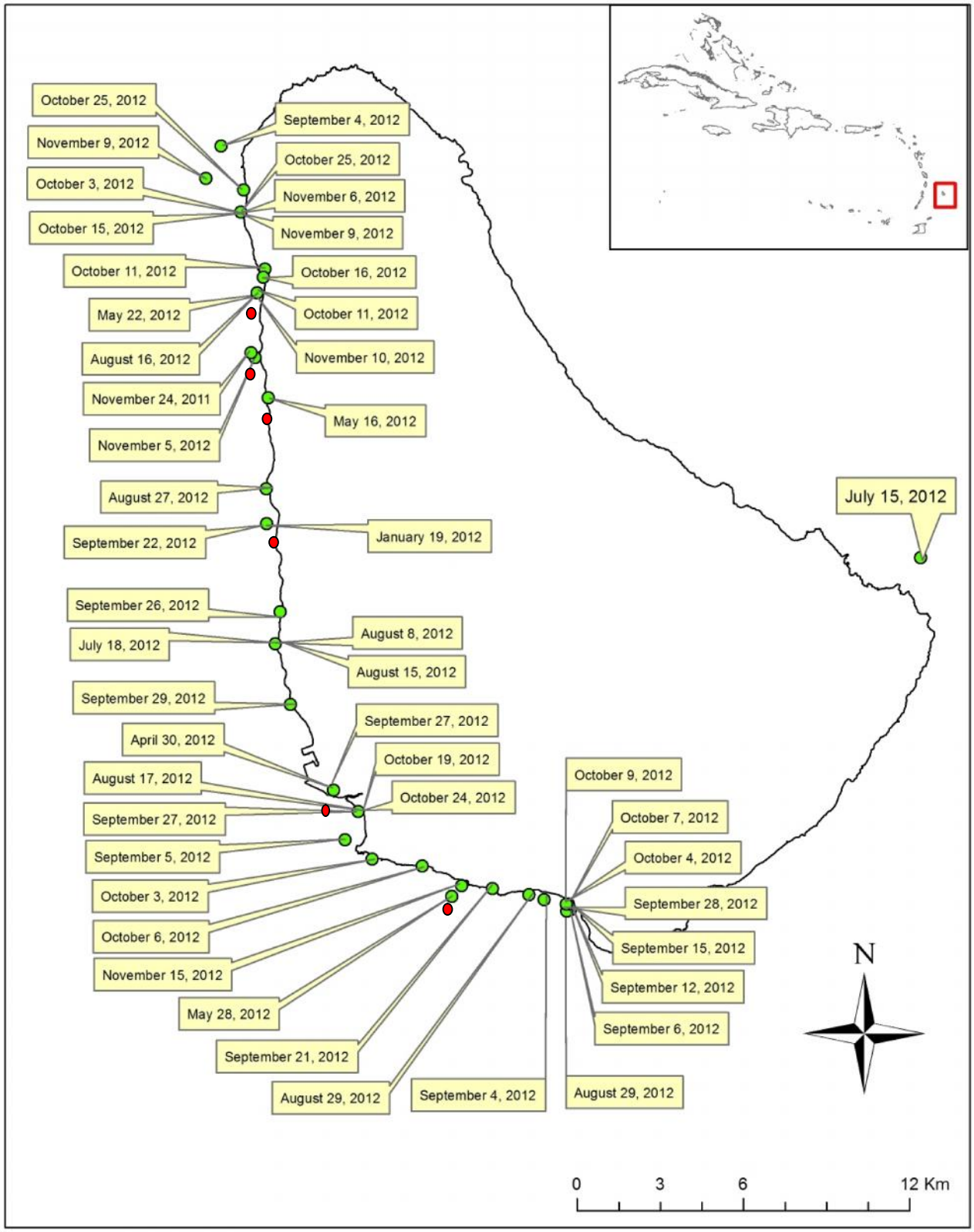

Figure 14. Dates and reported locations of all confirmed lionfish sightings (n=54) over the first year of the invasion (24 Nov 2011 – 15 Nov 2012) in Barbados. Arrivals over the first six months are shown in red. (Figure source: Sealy 2013)

5.3 Biological Characteristics

5.3.1 Data collection

All reported specimens that were captured, were collected or received by project personnel and were either processed fresh or were frozen for later examination. All biological data (morphometric measurements, weight, stomach content, gender, reproductive stage) were recorded on standardized forms (Appendix 9) following the detailed dissection guide of Green et al. (2012) and data were entered into the shared project database. Photographs of some of the first specimens are shown in Figure 15 and full details are recorded in the database (Appendix 8).

Figure 15. Examples of some of the first lionfish specimens caught in Barbados between November 2011 and November 2012.

5.3.2 Depth, habitat and lionfish behaviour

Not surprisingly, most sightings of lionfish were relatively shallow, although one was brought up in a fish pot set in an estimated 182 m (600 ft) of water off Harrisons Point. The full depth range was 1.5 – 182 m (Appendix 8) and the modal depth of reported sightings was 7.6 m. With the exception of a single specimen, the sighted lionfish were all reported to be active at the time of capture (hovering or swimming).

5.3.3 Maturity and gender

The gonads of 30 lionfish specimens were available for examination during the first year. Of these, most were immature (63%) or in the very 'early development' stage (20%). Just five specimens (17%) were found to be 'spawning capable' (see Appendix 9 for illustration of

maturity stages). These five specimens were all in excess of 180 mm TL, which corroborates with earlier studies of size at 50% maturity for lionfish from North Carolina and the Bahamas ranging from 100 mmTL for males to175 mmTL for females (Morris 2009). This supports the expectation that it is the early life history stages (pelagic eggs and larvae) that are first arriving in Barbados, such that the newly settled population is likely to be dominated by young, sexually immature individuals. Gender could only be assertained for eight specimens, from their gonads, and was found to be 1:1.

5.3.4 Size

Size was examined separately for the 'pioneer population' (i.e. those lionfish captured in Barbados during the first year of the invasion) and for the 'established population' (i.e. those captured in Barbados during Year 2 of the invasion.

Total length (TL) of the pioneers ranged from 59 mm to 285 mm (average length = 154 mm TL) and the average weight of the specimens was 64 g ranging from 2.1 g to 294.9 g (Figure 16). This pioneer population was clearly young, essentially comprising a single immature cohort and indicating the invasion was by the early life history stages and not adults.

Lionfish specimens collected from the established population in the second year of the invasion ranged in size from 68 mm to 369 mm (average length = 212 mm TL) and from 4 g to 799 g (average weight = 188 g) (Figure 16). The established population comprised two clear cohorts, an immature group of small individuals (average length = 165 mm TL), and an adult group of larger individuals (average length = 283 mm TL), suggesting a discrete annual recruitment either from the pioneer population and/or from a second pulse of invasion.

The strong length-weight relationship for the Barbados lionfish shown in Figure 17.

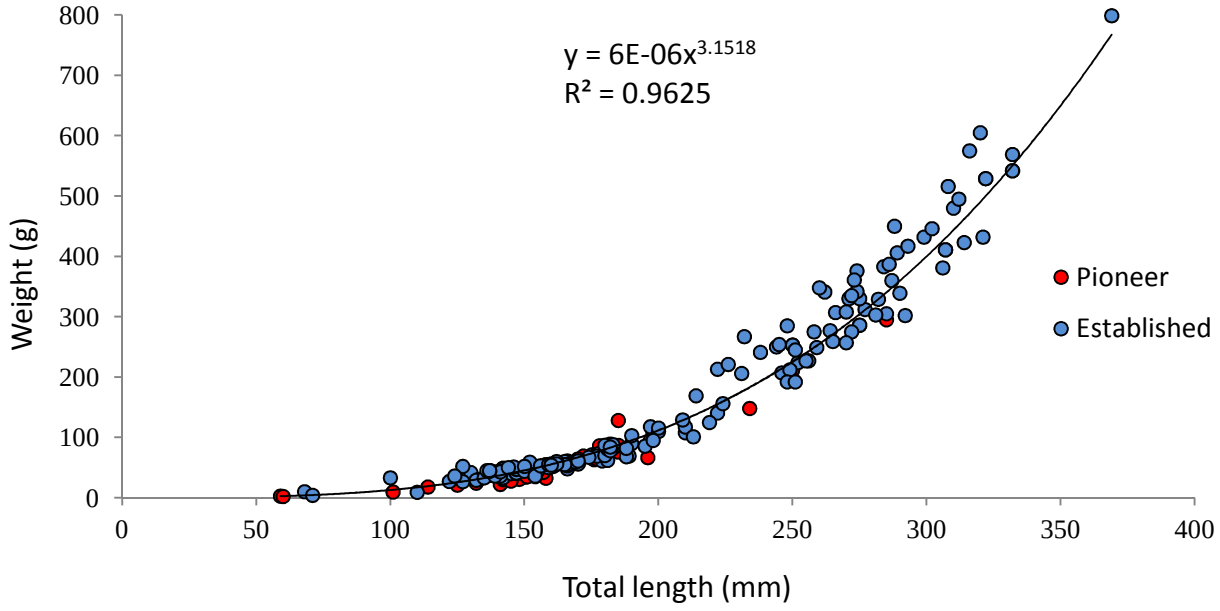

Figure 17. Length - weight relationship for all captured lionfish in Barbados (Nov 2011 - Sep 2013) showing individuals from the pioneer and established populations separately.

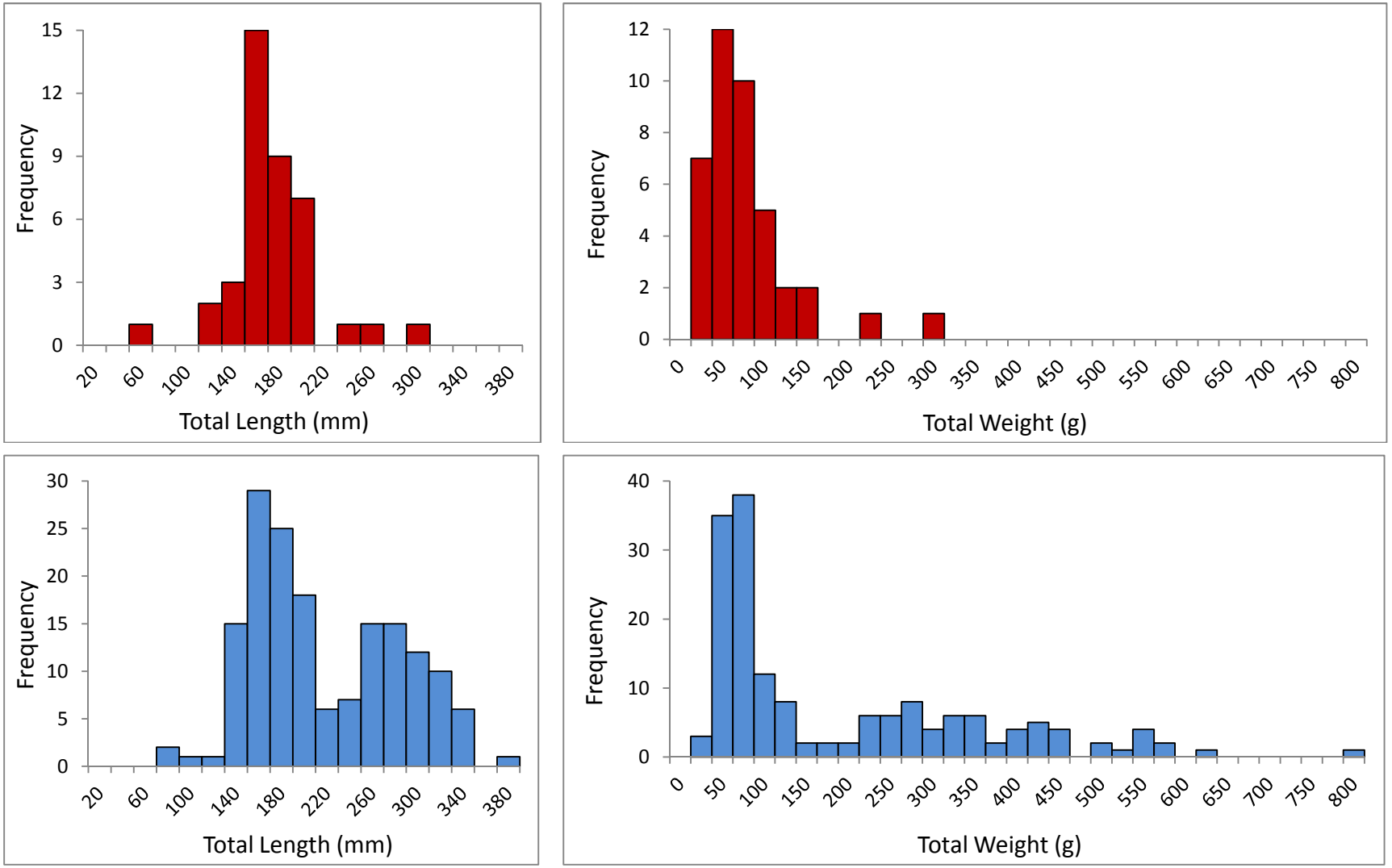

Figure 16. Size frequency distribution for the pioneer (red) lionfish population (sampled during Year 1 of the invasion) and the established (blue) lionfish population (sampled during Year 2 of the invasion), showing length (left panel) and weight (right panel) (adapted from Sealy 2013).

5.3.5 Diet

The stomachs of 30 lionfish were available for examination of contents. Of these, more than half of the stomachs were found to be either empty (20%) or had almost fully digested contents that could not be recognised (27%). The remaining specimens had consumed small fish (30%) ranging in size from 1.9 – 5 cmTL, small lobster pueruli (10%) and other small invertebrates (7%).

5.4 Genetic Identity of the Barbados Lionfish Population

The two lionfish species known to have established populations in the Western Atlantic (*Pterois volitans* and *P. miles*) are visually identical and can only be told apart by examining genetic markers (Hammer et al. 2007). To date, *P. volitans* is known to have spread up the east coast of the US, to Bermuda, to The Bahamas and into the Caribbean, but *P. miles* has not yet been found in the Caribbean (Betancur-R et al. 2011).

Furthermore, the genetic diversity of the alien lionfish populations in the Western Atlantic is greatly reduced compared with the native source populations in Western Indonesia, as a result of the small number of original specimens escaping or released into the wild in the Western Atlantic (i.e. a small founding population). This phenomenon is well known as the 'founder effect' and has resulted in the presence of just nine mtDNA d-loop haplotypes in the northern Western Atlantic populations. This genetic diversity has been further reduced (to 4 and 3 haplotypes), through one or more secondary founder effects, as *P. volitans* has spread across connectivity barriers into and across the Caribbean Sea from the original site of its introduction in Florida (Betancur-R et al. 2011). With each decrease in genetic diversity, the lionfish populations may become less adaptable and less resilient to environmental change.

The genetic characterization of Barbados lionfish sought to confirm the expectation of a single species, and to examine the genetic diversity of the population reaching this upwind, upcurrent and most easterly location in the Caribbean, with the expectation of finding only two or three d-loop haplotypes.

5.4.1 Data Collection, Laboratory Procedures and Analysis

Lionfish were collected in Barbados from the first reported arrival (24 Nov, 2011) until September 2013. Lionfish populations were sampled from each coastline (Figure 18). A small cube of muscle tissue from each specimen was preserved frozen or in DMSO for subsequent DNA extraction. A 680 bp fragment of the mitochondrial control region (d-loop) was amplified using lionfish specific primers [LionA-H (5-CCA TCT TAA CAT CTT CAG TG-3) and LionB-L (5-CAT ATC AAT ATG ATC TCA GTAC-3)] following Freshwater et al. (2009). All DNA extractions and amplifications were performed at Cave Hill Campus, University of the West Indies. Sequencing of all amplicons was performed by Molecular Cloning Laboratories (California, USA) and sequences were matched against published mtDNA control region

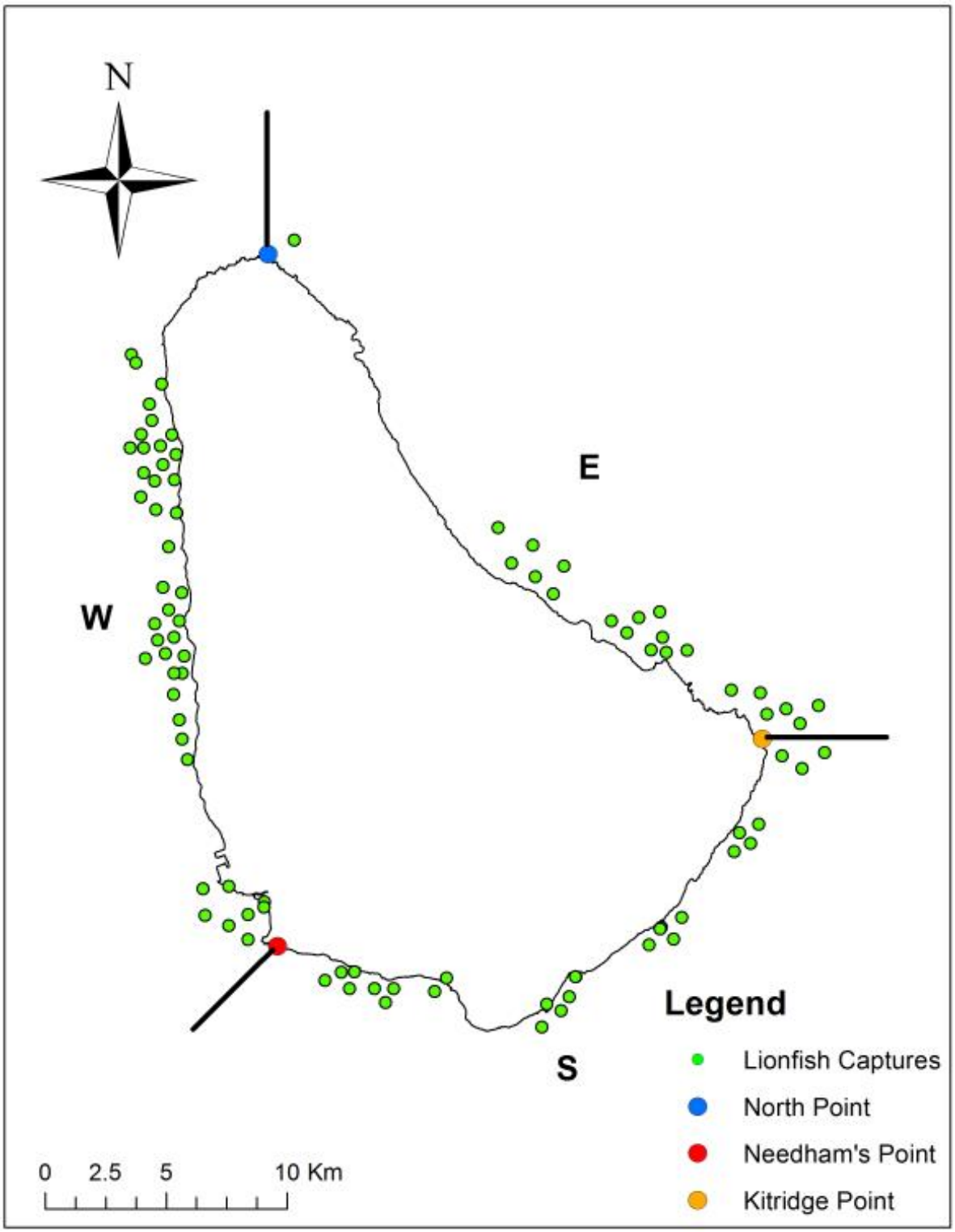

Figure 18. Approximate capture locations for lionfish specimens sampled between Nov 2011 and Sep 2013 from each coastline in Barbados for DNA analysis (adapted from Sealy 2013).

sequences using BioEdit. Measures of genetic diversity were calculated and analyses of molecular variance (AMOVA) were undertaken using Arlequin v. 3.5.

5.4.2 Species Identification and Genetic Diversity

All 178 amplicon sequences (679 bp) aligned with those of red lionfish (*Pterios volitans*) confirming our expectation of a single species lionfish invasion in Barbados to date. However, contrary to our expectation of finding just 2 or 3 haplotypes in the Barbados lionfish, a total of six haplotypes were detected (Table 5, Figure 19). All haplotypes detected in Barbados matched published Western Atlantic lionfish haplotypes H01, H02, H03, H04, H05 and H07 (GenBank accession numbers FJ516409–FJ516413 and FJ516415 registered by Freshwater et al. 2009). Also consistent with other studied Western Atlantic lionfish populations, two haplotypes were dominant: H01 found in 30.3% of our samples and H02 found in 65.7%, whilst the other haplotypes were relatively rare, each being found in less than 2% of samples. Calculated measures of genetic variation for the population in Barbados were low (e.g. haplotype diversity (HD) = 0.478) compared with those of native *P. volitans* populations (HD = 0.886 to 0.962, Betancur-R et al. 2011) but similar to other Western Atlantic invasive populations (Table 5).

Table 5. Summary of invasive Indo-Pacific red lionfish, *Pterois volitans*, d-loop haplotype presence/absence and haplotype diversity (HD) across the Western Atlantic populations

Group	Location	n	Haplotypes										HD
			H01	H02	H03	H04	H05	H06	H07	H08	H09	Total	
Northern	North Carolina[1]	264	✓	✓	✓	✓	✓	✓	✓		✓	8	0.704
	Bermuda[2]	45	✓	✓	✓			✓	✓			5	0.627
	Bahamas[1]	127	✓	✓	✓	✓	✓	✓	✓	✓		8	0.648
Central Caribbean	Grand Cayman[2]	79	✓	✓	✓	✓						4	0.432
	San Andrés[2]	50	✓	✓		✓						3	0.541
	Santa Marta[2]	169	✓	✓		✓						3	0.524
Eastern Caribbean	Puerto Rico[3]	118	✓	✓	✓	✓						4	0.449
	Barbados[4]	178	✓	✓	✓	✓	✓		✓			6	0.478

Data from [1] Freshwater et al. (2009), [2] Betancur-R et al. (2011), [3] Velez-Zuazo et al. (unpubl.), [4] this study.

5.4.3 Population Structuring

Despite differences in the presence of the rare haplotypes, there was no significant population structuring detected between the Year 1 pioneer (comprising H01, H02, H04) and Year 2 established (comprising H01, H02, H03, H04, H05 and H07) populations in Barbados (AMOVA: FST -0.0164, P = 0.947), nor among the three different coastal samples around the island (AMOVA: FST = -0.0118, P = 0.692, Figure 19).

5.4.4 Source Population

The presence of haplotypes H03, H05 and H07, which appeared in the second year of the invasion was unexpected, given that they have not previously been reported from the southern Caribbean (San Andrés, Santa Marta) lionfish populations. This finding raises the interesting question of whether Barbados received lionfish from one or more sources.

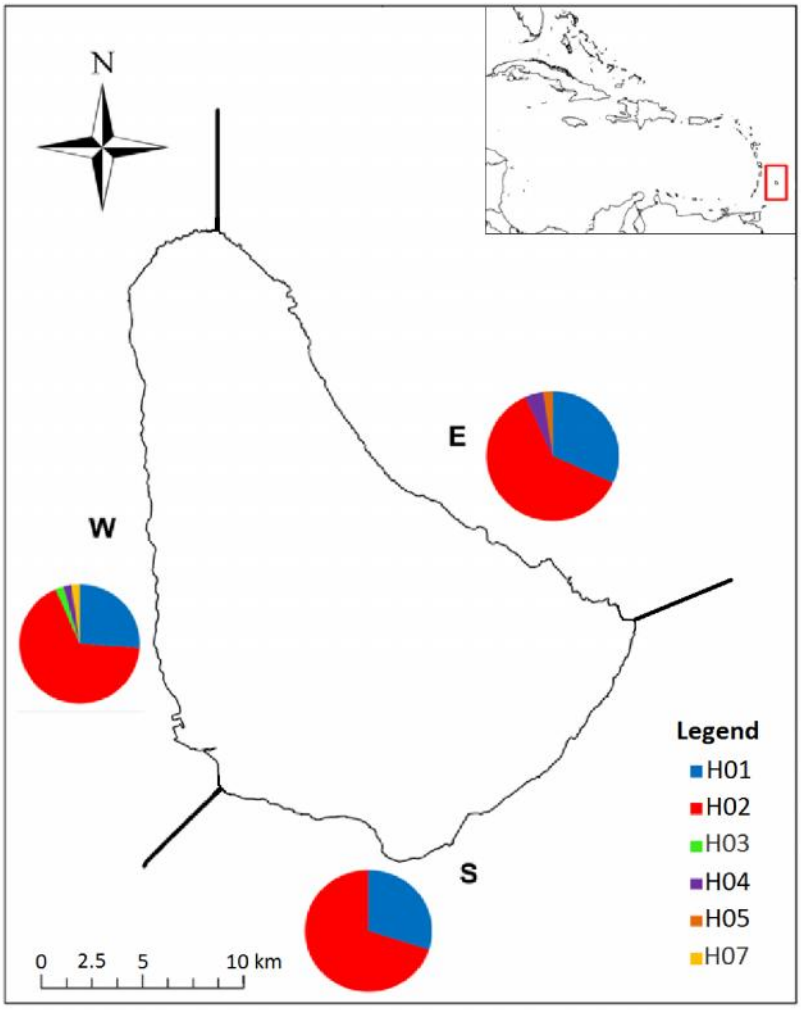

Figure 19. Red lionfish (*P. volitans*) haplotypic composition by coast in Barbados based on the 680 bp d-loop fragment sequences.

The bimodal size structure of the Barbados population in Year 2 indicates non-continuous recruitment which would support the idea of two separate invasion pulses to this up-current, upwind location. These pulses could conceivably have been from different sources. An analysis of molecular variance between the pioneer population in Barbados (Year 1) and the nearest populations within the Caribbean and Northern groups indicated no significant difference between Barbados and the southern Caribbean population (Santa Marta and San Andrés), whilst there was a significant difference between Barbados and the Northern population (AMOVA: Barbados vs Santa Marta FST = 0.00092, P = 0.324; Barbados vs Bahamas FST = 0.0734, P < 0.001), suggesting that the first pulse could have come from the southwest. An examination of the chronology of reported sightings (USGS-NAS database at http://nas.er.usgs.gov) indicates that lionfish were approaching Barbados in 2010 simultaneously from the southwest along the South American coastline and from the northwest down the Lesser Antilles island chain (Figure 20). However, from these data it would appear that the group spreading down the island chain from the north should have arrived first. This is also supported by the fact that the fish carrying H03 and H05 haplotypes, although not found until Year 2, were in fact mature fish (274-289 mmTL) and therefore likely arrived in the first pulse the year before. Since the other northern haplotype (H07) was found in the second year in a small fish (160 mmTL), this suggests that the second pulse also came from the northern populations. However, an analysis of molecular variance across all combinations of groups (Caribbean vs Northern, Barbados vs Caribbean, Barbados vs Northern) fails to detect any significant differences among groups (AMOVA FCT: P > 0.05 in all cases) although populations within groups showed significant variation (AMOVA FCS: P < 0.01 in all cases). A more extensive genetic analysis using samples from more locations will be required to better resolve the route of invasion and relatedness of island populations in the Eastern Caribbean.

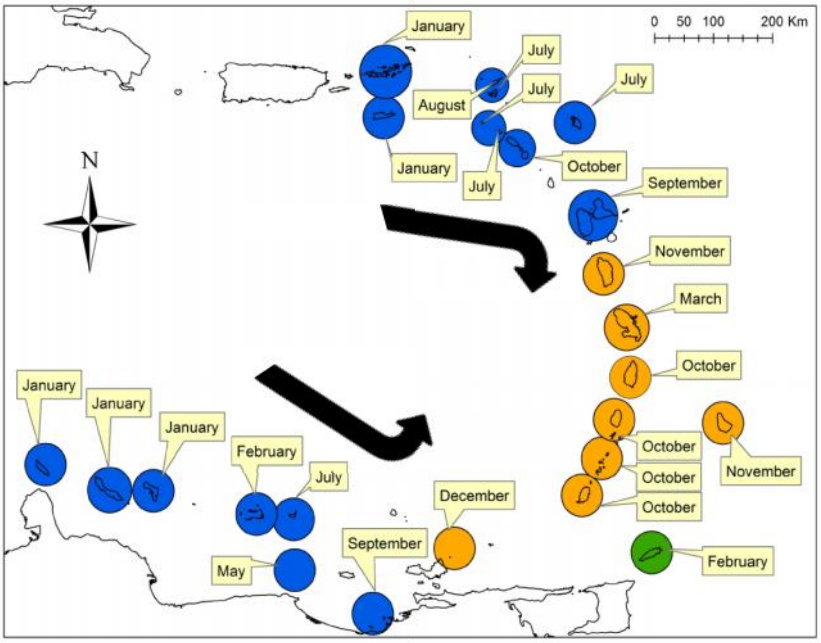

Figure 20. Map of the lionfish (*Pterois volitans*) invasion chronology in the Lesser Antilles from 2010 – 2012 as indicated by reported records to the USGS-NAS database at http://nas.er.usgs.gov. Black arrows indicate apparent directions of lionfish invasion. (Adapted from Sealy 2013).

6. CONCLUDING REMARKS

The project has been instrumental in forming a strong 'lionfish response' partnership between UWI, the CZMU and Fishery Divion which allowed us to effectively inform the public about lionfish and to track the first lionfish arrivals in Barbados. The public outreach and education, stakeholder training and lionfish research has continued via this partnership, beyond the end of this Lionfish Project funding and is now being sustained through the regular work plans and additional research grants within the partner institutions. This includes *inter alia*:

- Maintenance of the lionfish telephone hotline, facebook page, training and educational workshops by CZMU
- Regular culling dives by CZMU and FD staff at reported lionfish hotspots
- Liason with fishers and recreational divers and collection of specimens by CZMU, FD and CERMES
- Promotion of lionfish as a sustainable food and viable fishery by the CZMU and FD
- Plans to host the first Barbados Lionfish Derby competition sanctioned by the Barbados Government in 2014
- Initiation of research to investigate the genetic population structure and expansion of the now well established, but still relatively small, local lionfish population by CERMES.

The arrival of lionfish in Barbados occurred as predicted in late 2011 and the spread of this invasive species has followed the typical pattern seen elsewhere in the Caribbean, and typical of other invasive species, with a slow expansion of reported sightings over many months (population lag time) and then an exponential increase in number (see Figure 21).

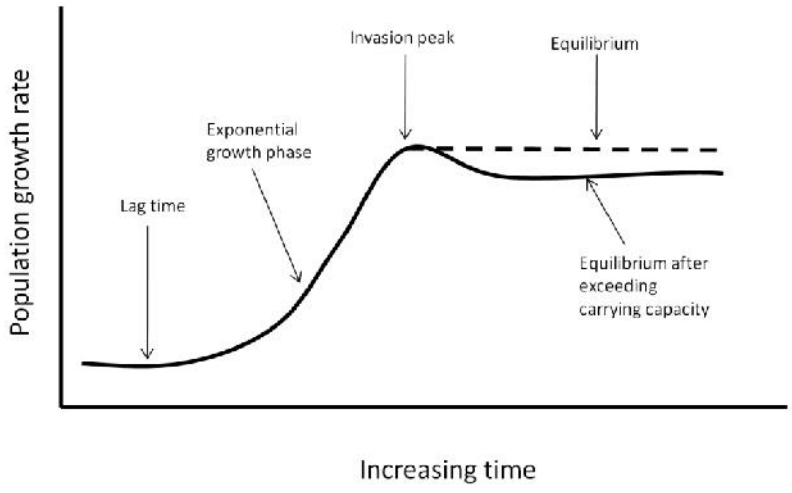

Figure 21. Simplified plot showing the predicted growth trajectory of an invasive species population over time. (Source: Morris *et al*. 2012)

The lionfish population in Barbados is clearly established, with the presence of many mature 'spawning capable' individuals. The substantial baseline data collected by this project and reported here on reef fish communities across Barbados' reefs and on the catches of reef fishers prior to the establishment of the alien lionfish population has served to inform Government's response to this major marine invasion. Further the shared baseline database provides a unique opportunity to measure the future impacts of this marine invasive species on the reef ecosystem services and fisher livelihoods in Barbados. We therefore strongly recommend that a new set of reef fisher and reef fish surveys be conducted if and when lionfish population increases to a point where it becomes a ubiquitous component of the reefs.

In addition to more population genetics work, future lines of research should consider specifically examining spatial patterns of lionfish distribution within and among reefs along Barbados coastline as well as examining temporal patterns of lionfish recruitment and potential ontogenetic shifts in habitat use.

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APPENDIX 1 – List of fish species and numbers recorded in the catches of trap and spear fishers in Barbados during the winter and summer fishing periods of 2013

Family groups	Species (common name)	Spear			Trap			Grand Total
		Survey 1 (Jan/Feb)	Survey 2 (Sep/Oct)	Total	Survey 1 (Jan/Feb)	Survey 2 (Sep/Oct)	Total	
Scaridae (parrotfishes)	Princess parrotfish	47	20	67	66	41	107	174
	Queen parrotfish		3	3	2	1	3	6
	Redband parrotfish	34	8	42	97	147	244	286
	Redtail parrotfish	21	19	40	28	34	62	102
	Stoplight parrotfish	112	37	149	116	67	183	332
	Striped parrotfish				12	13	25	25
	Unidentified parrotfish	1	2	3	2		2	5
	Yellowtail parrotfish	7	95	102				102
Haemulidae (grunts)	Black margate					1	1	1
	Bluestriped grunt					1	1	1
	Caesar grunt	4	36	40	8	12	20	60
	French grunt				69	35	104	104
	Sailors choice	1	1	2				2
	Smallmouth grunt				11	4	15	15
Carangidae (jacks)	Almaco jack	1	3	4	3		3	7
	Bar jack	21	23	44	13	32	45	89
	Blue runner jack	2	8	10	4		4	14
	Horseeye jack				2	2	4	4
	Yellow Jack	2	2	4	46	16	62	66
Acanthuridae (surgeonfishes)	Blue tang	3	19	22	41	18	59	81
	Doctorfish	1	8	9	17	1	18	27
	Ocean surgeon	7	11	18	22	22	44	62
Holocentridae (squirrelfishes)	Blackbar soldierfish				10	10	20	20
	Longspine squirrelfish	1		1	32	50	82	83
	Squirrelfish	9	26	35	17	3	20	55
Lutjanidae (snappers)	Glasseye snapper	11	40	51				51
	Gray Snapper	1		1				1
	Lane snapper	3		3	2		2	5
	Mahogany snapper	1	6	7	11	22	33	40
	Mutton snapper	10		10	7		7	17
	Red snapper	1		1				1
	Schoolmaster snapper	1	4	5		3	3	8
	Yellowtail snapper	3		3	2	1	3	6
Mullidae (goatfishes)	Spotted goatfish				3	15	18	18
	Yellow goatfish		2	2	36	38	74	76
Serranidae (groupers)	Coney	2	1	3		3	3	6
	Creole fish					1	1	1
	Graysby	29	8	37	15	18	33	70
	Rock hind				3		3	3

Family groups	Species (common name)	Spear			Trap			Grand Total
		Survey 1 (Jan/Feb)	Survey 2 (Sep/Oct)	Total	Survey 1 (Jan/Feb)	Survey 2 (Sep/Oct)	Total	
Monacanthidae (filefishes)	Orangespotted filefish		3	3	12	3	15	18
	Scrawled filefish		1	1	5	5	10	11
	Whitespotted filefish	9	7	16	12	3	15	31
Sphyraenidae (barracudas)	Great barracuda	30	2	32				32
Other	Banded butterflyfish				2		2	2
	Bermuda chub	6	4	10	1	3	4	14
	Black durgon	1	11	12		6	6	18
	Cero mackerel	3		3				3
	Damselfish				5		5	5
	French angelfish				1		1	1
	Grey triggerfish				1		1	1
	Honeycomb cowfish		1	1	1		1	2
	Ocean triggerfish	2		2				2
	Porgy		1	1				1
	Puddingwife	1	3	4				4
	Queen triggerfish		3	3		1	1	4
	Sergeant major				1		1	1
	Smooth trunkfish					1	1	1
	Spanish hogfish	8	7	15		4	4	19
Grand total		397	427	821	739	639	1375	2196
No. species		36	35	42	40	37	48	58

APPENDIX 2 – List of fish mean size (cm FL) by species and family landed by trap and spear fishers in Barbados during the winter and summer fishing periods

Family(groups)	Species (common name)	Spear				Trap			
		Survey 1 (Jan/Feb)	Survey 2 (Sep/Oct)	Overall		Survey 1 (Jan/Feb)	Survey 2 (Sep/Oct)	Overall	
		Mean FL (cm)	Mean FL (cm)	Mean FL (cm)	SD	Mean FL (cm)	Mean FL (cm)	Mean FL (cm)	SD
Scaridae	Princess parrotfish	23.7	22.9	23.5	2.6	19.6	20.6	20.0	2.2
(parrotfishes)	Queen parrotfish		32.7	32.7	7.1	19.0	17.7	18.6	0.8
	Redband parrotfish	24.2	24.6	24.3	2.8	18.7	18.4	18.5	1.4
	Redtail parrotfish	28.0	27.2	27.6	2.1	21.8	19.3	20.4	3.1
	Stoplight parrotfish	27.5	27.8	27.6	4.6	19.5	19.7	19.6	2.7
	Striped parrotfish					19.4	19.4	19.4	1.7
	Yellowtail parrotfish	26.1	26.0	26.0	3.1				
	Unidentified parrotfish	30.0	26.3	27.5	3.1	23.5		23.5	0.7
Haemulidae	Black margate						27.2	27.2	-
(grunts)	Bluestriped grunt						15.3	15.3	-
	Caesar grunt	22.0	23.4	23.3	1.8	17.7	18.5	18.2	2.8
	French grunt					16.7	16.6	16.7	1.2
	Sailors choice	27.2	34.0	30.6	4.8				
	Smallmouth grunt					16.9	18.1	17.2	1.0
Carangidae	Almaco jack	38.0	38.4	38.3	5.4	33.6		33.6	4.1
(jacks)	Bar jack	23.9	25.0	24.5	3.1	18.6	20.0	19.6	2.2
	Blue runner jack	20.3	25.7	24.6	3.9	19.3		19.3	1.9
	Horseeye jack					18.5	20.2	19.3	1.2
	Yellow Jack	23.8	26.5	25.1	1.6	23.3	18.0	21.9	3.8
Acanthuridae	Blue tang	21.9	20.1	20.3	2.1	14.5	16.2	15.0	2.7
(surgeonfishes)	Doctorfish	23.2	21.7	21.9	1.9	16.7	18.5	16.8	2.4
	Ocean surgeon	20.8	22.6	21.9	2.9	15.1	16.2	15.6	1.8
Holocentridae	Blackbar soldierfish					15.5	15.4	15.4	1.3
(squirrelfishes)	Longspine squirrelfish	19.5		19.5	-	18.3	18.7	18.6	1.2
	Squirrelfish	22.4	22.2	22.3	2.6	18.5	22.4	19.1	2.1
Lutjanidae	Glasseye snapper	23.7	24.4	24.3	2.5				
(snappers)	Gray Snapper	30.0		30.0	-				
	Lane snapper	22.3		22.3	2.1	18.5		18.5	2.1
	Mahogany snapper	25.8	28.3	27.9	2.1	22.9	22.4	22.6	2.9
	Mutton snapper	22.5		22.5	2.8	23.5		23.5	4.5
	Red snapper	25.4		25.4	-				
	Schoolmaster snapper	30.5	28.7	29.1	1.6		35.2	35.2	7.4
	Yellowtail snapper	34.8		34.8	8.5	19.4	20.0	19.6	1.2
Mullidae	Spotted goatfish					19.4	20.0	19.9	1.8
(goatfishes)	Yellow goatfish		24.9	24.9	2.8	20.3	21.0	20.6	1.9
Serranidae	Coney	24.9	25.9	25.2	0.7		22.2	22.2	3.5
(groupers)	Creole fish						19.6	19.6	-

Family(groups)	Species (common name)	Spear				Trap			
		Survey 1 (Jan/Feb)	Survey 2 (Sep/Oct)	Overall		Survey 1 (Jan/Feb)	Survey 2 (Sep/Oct)	Overall	
		Mean FL (cm)	Mean FL (cm)	Mean FL (cm)	SD	Mean FL (cm)	Mean FL (cm)	Mean FL (cm)	SD
	Graysby	24.6	25.3	24.8	2.2	23.2	23.2	23.2	2.9
	Rock hind					21.8		21.8	2.8
Monacanthidae (filefishes)	Orangespotted filefish		26.5	26.5	3.3	17.5	23.7	18.7	5.9
	Scrawled filefish		51.2	51.2	-	43.5	42.3	42.9	2.3
	Whitespotted filefish	25.3	26.4	25.8	1.8	25.2	27.7	25.7	2.7
Sphyraenidae (barracudas)	Great barracuda	57.1	73.8	58.1	14.9				
Other	Banded butterflyfish					12.2		12.2	1.6
	Bermuda chub	26.2	25.7	26.0	2.3	21.9	23.2	22.9	1.1
	Black durgon	27.0	21.3	21.8	2.2		21.1	21.1	2.8
	Damselfish					13.2		13.2	0.8
	French angelfish					31.5		31.5	-
	Grey triggerfish					24.0		24.0	-
	Honeycomb cowfish		38.6	38.6	-	18.0		18.0	-
	Ocean triggerfish	37.1		37.1	0.4				
	Porgy		16.5	16.5	-				
	Puddingwife	32.5	34.3	33.9	2.2				
	Queen triggerfish		31.1	31.1	6.7		28.7	28.7	-
	Sergeant major					12.0		12.0	-
	Smooth trunkfish						16.0	16.0	-
	Spanish hogfish	26.2	25.1	25.7	2.6		22.8	22.8	3.2
	Cero mackerel	51.3		51.3	4.9				
Grand total		28.2	25.4	26.7	8.2	19.2	19.5	19.4	3.9

APPENDIX 3 – Standardized sampling protocol for reef fish community surveys

FINALISED SAMPLING PROTOCOL

- A minimum of 10 transects are surveyed on each reef site.
- Where the reef is large enough all transects are set 30m apart in all directions.
- On west coast fringing reefs transects are set on the reef near the seaward edge and oriented to run across the spur and grooves (NOT along a spur), and set in a line end to end, at least 30 m apart.
- For small fringing reefs transects may have to be laid parallel or perpendicular to one another to fit onto the reef to maximise the surface area while obtaining the maximum possible distance between transects.
- On narrow bank reefs, the transects run parallel to one another and to shore, they are separated by 10-15 metres. On these banks, the transects are along the top of the reef crest.
- For fringing reef sites, the site set up is drawn up using a Google Earth image of the reef and the positions of each transect are loaded into the GPS. On location, the site is set up using a GPS before divers enter the water. This involves placing a marker at the beginning of each 30m transect so that divers can set their own compass courses and be dropped in the correct position to start, and can find the next transect when the first is complete.
- Each transect is 30m x 2 m for large mobile fish (LF) and 30m x 1m for slow moving, attached species, territorial slow moving fish (SF).
- Each transect is surveyed by making two passes. The first to record slow moving/attached species, the second to record mobile species.
- Mobile (**large**) species include MOSTLY **commercially important** species (i.e. butterflyfishes, angelfishes, parrotfishes, grunts, snappers, surgeonfishes, groupers, jacks, squirrelfishes, chubs, mackerels, yellowtail damselfish, barracudas, hogfishes, razorfishes, big eyes, lizardfishes, flounders, scorpionfishes except lionfishes, flying gurnards, boxfishes, pufferfishes, porcupinefishes, triggerfishes, filefishes, drums, goatfishes, tilefishes, and a few others (i.e. trumpetfishes, chromis, hamlets, soapfishes, basslets, frogfishes)
- Slow moving (**small**) fish include only **non-commercial species** (i.e. bicolor damselfish, other damselfishes [EXCEPT yellowtail damselfish], bluehead wrasse, yellowhead wrasse, clown wrasse, slippery dicks and miscellaneous wrasses, lionfishes and *Diadema*. All other 'cryptic' species are to be ignored.
- First the diver lays down the 30m tape and waits a few minutes for the fish to settle
- In the second sweep, using a 1m pole, all *Diadema* are counted and each of the slow moving fish species are identified and placed in one of three size categories accordingly: S1 <5cm, S2 >5cm <10cm and S3 >10cm
- On the first sweep the most skittish species (the mobile species) are recorded. All mobile fish (LF) within a 2 m band are identified to species, counted and sized to the nearest cm. The diver uses a 2m pole to demarcate the width.
- Data are collected onto pre-marked underwater slates, which are photocopied and archived on return to shore. Data are then entered into standard template in an excel spreadsheet.
- The tape is rolled up after the data are collected and the diver swims along the same transect line to the end of the 30m and then swims on a compass bearing to the next transect. Each diver collects data from a minimum of two transects.

APPENDIX 4 – Nation newspaper article on lionfish arrival and research project

captain and is considered one of the island's most decorated volleyballers, will reappear in court on May 21. (DP) (Picture by Maria Bradshaw.)

LIONFISH HERE

by MARIA BRADSHAW

AFTER YEARS OF SPECULATION, the dangerous and invasive lionfish has finally been caught in Barbados.

The **MIDWEEK NATION** was recently informed that three weeks ago a spear diver caught the pretty but predatory fish on the West Coast, just off Porters, St James.

The fish was placed on ice and handed over to officials at the Coastal Zone Management Unit (CZMU) before being taken to the Fisheries Division.

Fisherman Chelston Thomas expressed concern that up to this day the public had not been alerted about the catch, even though the Fisheries Division had promised "to inform the public when the fish had reached our waters and the steps to take to control them", he said.

He pointed out that divers had gone out to the area where the fish was caught looking for more but had not located any. However, he said that the divers had reported seeing fish with their tails and wings bitten off – evidence that the lionfish had started its damage.

When contacted yesterday, Caroline Bissada, a marine biologist who has been hired by the Centre for Resource Management And Environmental Studies (CERMES) to conduct fieldwork on the lionfish in Barbados, confirmed that the first lionfish was indeed caught.

Collaborative effort

She stated that CERMES, the Fisheries Division and the CZMU had undertaken a collaborative effort to map the lionfish's invasion and to inform the public about the fish and what to do if any was sighted.

The dangerous fish has already established itself throughout most of the Caribbean and has invaded the Leeward Islands.

The lionfish reproduces rapidly and is a voracious predators of reef fish. Once established, the lionfish population is capable of decimating the local reef fish population, which plays various important roles in maintaining the balance, health and functions of the coral reef and ecosystem.

Bissada, who has set up a **Facebook** page and a hotline, said the three organizations had been busy spreading the word about the lionfish since the beginning of the year and they had held meetings with fishermen and divers to inform them what to do if they were stung by the fish.

Lionfish possess venomous spines capable of deterring predators and inflicting serious stings and reactions in humans.

Bissada urged people to contact the hotline at 824-8361 and provide the precise location of any sightings so that the area could be easily mapped.

The two species sighted in the Caribbean are the red lionfish and the devil firefish. The lionfish can live up to 15 years. They also have very few natural enemies in the western Atlantic.

Earlier this year the three organizations posted leaflets in which they asked divers, fishermen and seabathers to be on the alert. They also advised that while the fish was tasty when cooked, people needed to know how to safely fish for and process the lionfish.

"Without this knowledge, do not touch or handle these fish," was the warning issued.

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APPENDIX 5 – First Barbados lionfish brochure providing information

Monitoring and Control

- All divers, fishermen and sea bathers are asked to be on the lookout for these fish.
- If you encounter them please record the date and location of the sighting and inform the Fisheries Division or Coastal Zone Management Unit as soon as possible.
- Lionfish are tasty and they are now fished and eaten in many countries in which they have become established. The toxin is not in the flesh itself and cooking will remove any traces accidentally left from processing.
- However, one needs to know how to safely fish for and process lionfish. Without this knowledge, do not touch or handle these fish.
- The public will be informed when these fish reach our waters and of the steps to control them.

Red lionfish - Image by NOAA

Human Health Threats

Lionfish have sharp spines by which they deliver a toxin into the skin that causes severe pain and swelling. However, the toxin is rarely fatal.

Venomous spines of the Lionfish - Image by NOAA

If stuck with a lionfish spine:

1. Remove all traces of the spine.
2. Irrigate the wound with water as hot as can be tolerated without burning the skin for at least 30 minutes. The hot water degrades the toxin and reduces its spread and effects.
3. Seek professional medical help.

Fisheries Division,
Ministry of Agriculture,
Food, Fisheries, Industry
and Small Business
Development
Bridgetown
Tel: 4263745/ 4265973/
4278480
Fax: 4369068
fishbarbados@caribsurf.com

Coastal Zone
Management Unit
Bay Street,
St. Michael.
Tel: 2285950/ 1/2
Fax: 2285956
info@coastal.gov.bb

Lionfish

The red lionfish - Image by NOAA

If you see this beautiful but dangerous fish DO NOT TOUCH IT but please let us know immediately where and when you saw it

Please call:

Fisheries Division
Tel: 4263745/ 4265973/ 4278480
Or:
Coastal Zone Management Unit
Tel: 228 5950/1/2

LIONFISH HOTLINE 824-8361

All Divers, Fishermen and Sea Bathers Be Aware! Some Important Facts About the Lionfish

Native range

- There are several species of lionfish and all are native to the Indian and Pacific Oceans.

Invading species

- Only two of these species namely **red lionfish (*Pterois volitans*)** and **devil firefish (*Pterois miles*)** are known to be now spreading through the western Atlantic.
- These two species look very similar and are not easily distinguished.
- However, it is mainly the red lionfish that is now the most common in the western Atlantic region.
- It must be stressed that **there are no native species of lionfish in the Caribbean** although our native species of scorpionfish is often referred to as 'lionfish', 'sculpin' or 'stonefish' in Barbados.

Distribution

- Lionfish were first observed off the Florida coast in 1992.
- By 2010 lionfish had spread as far north as Rhode Island in the USA, throughout most of the Caribbean and along the north coast of South America, as far east as Venezuela
- Lionfish have already invaded all of the Leeward Islands.
- **It is expected that lionfish will soon reach the Windward Islands including Barbados.**

Distribution of lionfish across the western Atlantic by 2010. Image by NOAA

Biology

- Lionfish can live up to 15 years and attain maximum sizes of 45 cm in length and around 1.2 kg in weight.
- Lionfish reproduce rapidly and are voracious predators of reef fish.
- Lionfish have very few natural enemies in the western Atlantic.

Ecological and socioeconomic threats

- Once established, a lionfish population is capable of decimating local native reef fish populations that play various important roles in maintaining the balance, health and functioning of the coral reef ecosystem.
- This includes types of small fish that are important as food for the larger fish, such as snappers, that we eat.
- Loss of these fish can seriously damage the coral reef ecosystem and associated fisheries and recreational industries.

APPENDIX 6 – Second Barbados lionfish brochure requesting samples

We want to know:

- Date of sighting
- Time of sighting
- Location:
  - Site name
  - Landmarks
  - Latitude
  - Longitude
- Depth
- Habitat type:
  - Sand– Rubble-
  - Reef-Sea grass
- What were you doing when you spotted it?
  - Diving –Fishing–
  - Swimming-Other
- Number of fish? observed
- Size of fish
- What was the fish doing?
  - Hiding– Hovering–
  - Swimming– Feeding

If stung:

- Remove all spines
- Immerse wound in hot but non scalding water (100-110 F° or 38-43 C°) for 45 minutes

DO NOT APPLY ICE
OR
COLD WATER

Image by H.A. Oxenford

Fisheries Division, Ministry of Agriculture, Food, fisheries, Industry and Small Business Development
Bridgetown
426-3745/ 5973
fishbarbados@caribsurf.com

Coastal Zone Management Unit, Ministry of Environment and Drainage
Bay street,
St Michael
228-5950/1/2
info@coastal.gov.bb

LIONFISH

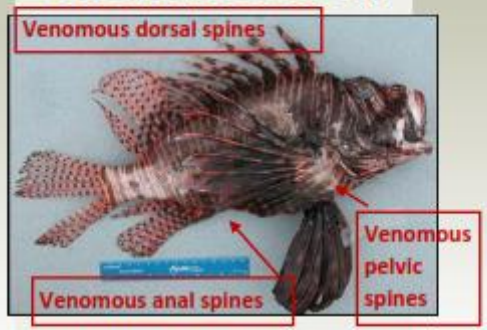
Image by H.A. Oxenford

WANTED

DEAD OR ALIVE

LIONFISH HOTLINE:
824-8362
COASTAL ZONE MANAGEMENT UNIT:
228-5950
FISHERIES DIVISION:
426-3745

Identification



- Lionfish have distinctive red, maroon, and white vertical stripes
- Fleshy tentacles above eyes and below mouth
- Fan-like fins
- Long separated dorsal spines

Lionfish facts

- Invasive species
- Native to the Indian and Pacific Ocean
- No natural predators in the Caribbean
- Outcompete local fish for food
- Can grow ≥ 45cm
- Mature < 1 year
- Reproduce every 4 days year-round
- Female can spawn ~ 2 million eggs per year in the Caribbean
- Lionfish can be eaten!

Local fish commonly mistaken for Lionfish

APPENDIX 7 – Standard lionfish sighting form

LIONFISH SIGHTING FORM

The red lionfish (*Pterois volitans*). Image courtesy NOAA

Coastal Zone Management Unit
Bay Street, St. Michael.
Tel: 2285950/ 1/ 2
Fax: 2285956
info@coastal.gov.bb

Fisheries Division,
Ministry of Agriculture, Food,
Fisheries, Industry and
Small Business Development
Bridgetown
Tel: 4263745/ 4265973/ 4278480
Fax: 4369068
fishbarbados@caribsurf.com

RECORD NO (*Official use only*): _____

Data Recorder: _____ ***Contact #***: _____

Observer _____
(if not the same as Recorder): ***Contact #***: _____

Date of sighting: (dd/mm/yy) ___/___/___ ***Time of sighting:*** _____

Sighting Location:
Site Name: _____ Landmarks: _____

Latitude: _____ Longitude: _____

Depth: _____

Habitat Type:
☐ Sand ☐ Rubble ☐ Patch Reef ☐ Bank Reef ☐ Fringe Reef ☐ Sea grass
☐ Other (Specify) _____

Activity of the observer:
☐ Diving ☐ Fishing ☐ Swimming ☐ Other (Specify) _____

Number of lionfish observed: _____

Approximate size (or size range if more than 1 fish) _____ (cm/ inches)

What was the lionfish doing?
☐ Hiding ☐ Hovering ☐ Swimming ☐ Feeding ☐ Other (Specify) _____

Was fish caught? If yes what gear was used? _____

PLEASE SUBMIT COMPLETED FORM TO THE FISHERIES DIVISION OR COASTAL ZONE MANAGEMENT UNIT. PLEASE CALL IF YOU NEED THE FORM COLLECTED.

APPENDIX 8 –Records of first lionfish arrivals in Barbados

Fish ID	Date	Observer Category	Coast	Site name	Habitat	Latitude	Longitude	Depth (m)	Total Length (cm)	Weight (g)	Sex	Maturity stage
1	24-Nov-11	SCUBA diver	West	Heymans reef		13.238344	-59.649397	15.2	193			
2	19-Jan-12	SCUBA diver	West	Fishermans reef		13.182431	-59.644139	21.2	212			
3	30-Apr-12	SCUBA diver	South	BFC	rubble	13.095398	-59.621891	16.2	181		Female	ED
4	16-May-12	Trap fisher	West	Mullins	fish pot	13.223547	-59.643588	3.1	285	294.9		
5	22-May-12	SCUBA diver	West	Pamir Wreck		13.25786	-59.647236	12.2	185	75.8		
6	28-May-12		South	Bourgainvillia		13.060694	-59.582465					
7	18-Jul-12	Spearfisher	west	Fitz Village		13.143281	-59.641203	3.0				
8	15-Jul-12	Other	East	Ragged Point	reef	13.171296	-59.426388	30.5	185	128.1	Female	SC
9	8-Aug-12	Spearfisher	West	Fitz Village	patch reef	13.143281	-59.641203	4.6				
10	15-Aug-12	SCUBA diver	West	Fitts Village	patch reef	13.143281	-59.641203	1.4	114	17.8	Male	I
11	16-Aug-12	SCUBA diver	West	Pamir Wreck	patch reef	13.25786	-59.647236	16.8	59	2.7		
12	17-Aug-12	SCUBA diver	South	Carlisle Bay		13.088421	-59.613622	8.2	132	24.2		I
13	27-Aug-12	SCUBA diver	West	Coral Reef Hotel	patch reef	13.193828	-59.644337	19.8	150	34.2		I
14	29-Aug-12	SCUBA diver	South	Oistins	sand	13.056252	-59.542941	24.4	145	33.9		ED
15	29-Aug-12	Spearfisher	South	Enterprise	rubble	13.061248	-59.556737	7.6	142	30.5		ED
16	4-Sep-12	Trap fisher	north	Harrison Point	rubble	13.305806	-59.659402	182.0	250	211.5	Female	SC
17	4-Sep-12	Spearfisher	South	Oistins	patch reef	13.059607	-59.551723	15.2	158	45.5		ED
18	5-Sep-12	SCUBA diver	South	Hilton	sand	13.079176	-59.618044	15.2	141	22.1		ED
19	6-Sep-12	Trap fisher	South	Oistins	rubble	13.055904	-59.544216	30.5	234	148	Male	SC
20	12-Sep-12	Spearfisher	South	Oistins	patch reef	13.058184	-59.543661	19.8	142	30		I
21	15-Sep-12	Spearfisher	South	Oistins		13.058184	-59.543661		152	56.5		
22	Sep-12	SCUBA diver							148	30.4		
23	Sep-13	SCUBA diver							60	2.1		
24	6-Sep-12	Other	South	Pebbles Beach					145	27.6		
25	21-Sep-12	Spearfisher	South	Off Dover Beach Hotel	reef	13.063211	-59.568963	9.1	176	71.6		

Fish ID	Date	Observer Category	Coast	Site name	Habitat	Latitude	Longitude	Depth (m)	Total Length (cm)	Weight (g)	Sex	Maturity stage
26	22-Sep-12	SCUBA diver	West	Dottins Reef	bank reef	13.182431	-59.644139	13.0	152			
27	26-Sep-12	SCUBA diver	West	Paynes Bay	sand	13.153642	-59.639676	4.3	101	9.5	Male	I
28	27-Sep-12	Spearfisher	South	BFC		13.096013	-59.622785	6.1	176	63		
29	27-Sep-12	SCUBA diver	South	Carlisle Bay	sand	13.088184	-59.611832	7.6				
30	Sep-12	SCUBA diver	West	Pile Bay					158	32.4		
31	29-Sep-12	Spearfisher	West	Off Hot Pot	patch reef	13.123464	-59.636224	6.1	180	67	Male	SC
32	3-Oct-12	SCUBA diver	South	Drill Hall	patch reef	13.072877	-59.608915	24.4	168	56.8		
33	3-Oct-12	SCUBA diver	South	Drill Hall	patch reef	13.072877	-59.608915	12.0				
34	3-Oct-12	Trap fisher	West	Cement Factory	patch reef	13.284229	-59.652795	9.1	167	54.7		I
35	28-Sep-12	Spearfisher	South	Oistins	bank reef	13.058146	-59.544324	22.0				
36	3-Oct-12	Spearfisher	South	Oistins	rubble	13.058146	-59.544324	18.3	177	64.1		i
37	4-Oct-12	Spearfisher	South	Oistins	rubble	13.059136	-59.543625	9.1				
38	6-Oct-12	SCUBA diver	South	Accra Bank	bank reef	13.070677	-59.592297	24.0	197	95.7		I
39	7-Oct-12	Trap fisher	South	Oistins	sand & rubble	13.057913	-59.545099	22.9	157	42		I
40	9-Oct-12	Other	South	Oistins	sand	13.061611	-59.543459	9.1	196	66.5		
41	11-Oct-12	SCUBA diver	West	Pamir Wreck	patch reef	13.25786	-59.647236	13.7	172	69.2		I
42	15-Oct-12	SCUBA diver	West	Cement Factory	rubble	13.284229	-59.652795	9.1	192			
43	16-Oct-12	Spearfisher	West	Port St Charles		13.262907	-59.645259					
44	11-Oct-12	Spearfisher	West	Port Ferdinand	offshore breakwater	13.265687	-59.64466	1.5	180	79.3		I
45	19-Oct-12	SCUBA diver	South	Carlisle Bay	concrete	13.088184	-59.611832	12.0				
46	24-Oct-12	SCUBA diver	South	Carlisle Bay	wreck	13.088184	-59.611832	12.0				
47	24-Oct-12	SCUBA diver	South	Carlisle Bay	wreck	13.088184	-59.611832	12.0				
48	25-Oct-12	Spearfisher	West	Cement Factory	sand & rocks	13.291481	-59.651861	6.1	170	64.3		I
49	5-Nov-12	SCUBA diver	West	Bombass Reef	bank reef	13.236681	-59.648009	12.2	178	86.2		I
50	6-Nov-12	SCUBA diver	West	Cement Factory	sand & rubble	13.284229	-59.652795		145	40		I
51	9-Nov-12	SCUBA diver	West	Maycocks	bank reef	13.295256	-59.664381	16.8	125	20.9		I
52	9-Nov-12	SCUBA diver	West	Cement Factory	sand & rubble	13.285021	-59.652754	7.6	151	34.6		I
53	9-Nov-12	SCUBA diver	West	Cement Factory	sand & rubble	13.285021	-59.652754	7.6	185	86.9		I
54	9-Nov-12	SCUBA diver	West	Cement Factory	sand & rubble	13.285021	-59.652754	7.6	130	32.2		I

Fish ID	Date	Observer Category	Coast	Site name	Habitat	Latitude	Longitude	Depth (m)	Total Length (cm)	Weight (g)	Sex	Maturity stage
55	10-Nov-12	SCUBA diver	West	Pamir Wreck	wreck	13.25786	-59.647236	12.2	198	107.2		
56	15-Nov-12	SCUBA diver	South	Graeme Hall Shallows	bank reef	13.064216	-59.579158	24.4	198	109.5	Female	SC
57	Nov-12		West	Bombass Reef		13.236681	-59.648009		142	37.8		
58	21-Nov-12											
59	27-Nov-12		South	Gemswick					222	140.5		
60	27-Nov-12		South	Gemswick					154	37		I
61	27-Nov-12		South	Gemswick					190	89.9	Female	DFV
62	27-Nov-12		South	Gemswick					142	33		I
63	Nov-12		South	Gemswick					155	44.8		I
64	29-Nov-12		South	Gemswick						90.1		I
65	29-Nov-12		South	Gemswick					210	107.7	Female	ED
66	29-Nov-12		South	Gemswick					197	117.7		ED
67	5-Dec-12		West	Off Pile Bay					219	124.7		
68	5-Dec-12		South	Crane					200	110		
69	Dec-12		West	Atlantis reef	bank reef				200	115.5	Female	
70	13-Dec-12		East	Consett Bay		13.184757	-59.46594		130	41.7		
71	Dec-12		West	Pile Bay					170	57.7	Female	ED
72	Dec-12		West	Pile Bay					210	117.3		
73	Dec-12		East	Bath					175	70.8		
74	Dec-12		East	Bath					133	30.5		
75	Dec-12		East	Bath					127	26.6		
76	21-Jan-13		West						195	85.5	Female	ED
77	Jun-13		South	Carlisle Bay		13.088421	-59.613622		189	69.1		
92	5-May-13		South	Carlisle Bay		13.088421	-59.613622	33.9	260	348		
93	5-May-13		South	Carlisle Bay		13.088421	-59.613622	33.9	200			
94	Jun-13		East	Consett Bay		13.184757	-59.46594		248	285		
95	Jun-13		East	Consett Bay		13.184757	-59.46594		369	799		
96	Jun-13		East	Consett Bay		13.184757	-59.46594		266	307		
97	Jun-13		East	Consett Bay		13.184757	-59.46594		252	224		

Fish ID	Date	Observer Category	Coast	Site name	Habitat	Latitude	Longitude	Depth (m)	Total Length (cm)	Weight (g)	Sex	Maturity stage
98	19-Jun-13		West	Brightledge				15.4	181	87		
99	19-Jun-13		West	Brightledge				15.4	281	303		
100	19-Jun-13		West	Brightledge				15.4	270	308		
101	19-Jun-13		West	Brightledge				15.4	213	101		
102	20-Jun-13		West	Tropicana Reef				16.9	249	212		
103	20-Jun-13		West	Tropicana Reef				16.9	150	44		
104	20-Jun-13		West	Tropicana Reef				16.9	183	82		
105	20-Jun-13		West	Fisherman's Reef		13.182431	-59.644139	18.5	154	35		
106	21-Jun-13		West	Tropicana Reef				16.9	238	241		
107	21-Jun-13		West	Tropicana Reef				16.9	141	36		
108	24-Jun-13		West	Pamir Wreck		13.25786	-59.647236	21.6	159	50		
109	Jul-13								275	330		
110	Jul-13			Bonucuda Ground				24.6	272	275		
111	Jul-13			Clubb Ground				15.4	231	206		
112	16-Jul-13		South	Long Bay				21.6	271	330		
113	16-Jul-13		South	Long Bay				21.6	222	213		
114	16-Jul-13		South	Long Bay				21.6	284	383		
115	22-Jul-13		West	Fisherman's Reef		13.182431	-59.644139	18.5	139	36		
116	22-Jul-13		West	Fisherman's Reef		13.182431	-59.644139	18.5	248	192		
117	24-Jul-13		South	Carlisle Bay		13.088421	-59.613622	13.9	226	221		
118	26-Jul-13		West	Fisherman's Reef		13.182431	-59.644139	18.5	286	387		
119	29-Jul-13		West	Stavronikita				30.8	209	129		
120	Aug-13								292	302		
121	Aug-13								287	360		
122	Aug-13								312	495		
123	Aug-13								161	53		
124	Aug-13								290	339		
125	2-Aug-13		South	Carlisle Bay		13.088421	-59.613622	15.4	68	10		
126	7-Aug-13		West	Dottin's Reef		13.182431	-59.644139		224	156		

Fish ID	Date	Observer Category	Coast	Site name	Habitat	Latitude	Longitude	Depth (m)	Total Length (cm)	Weight (g)	Sex	Maturity stage
127	7-Aug-13		West	Dottin's Reef		13.182431	-59.644139		165	55		
128	7-Aug-13		West	Dottin's Reef		13.182431	-59.644139		188	82		
129	7-Aug-13		West	Dottin's Reef		13.182431	-59.644139		71	4		
130	7-Aug-13		West	Dottin's Reef		13.182431	-59.644139		181	82		
131	23-Aug-13		West	Great Ledge					251	192		
132	23-Aug-13		West	Great Ledge					262	341		
133	23-Aug-13		West	Great Ledge					274	342		
134	24-Aug-13		West	Maycock's Reef		13.295256	-59.664381		181	81		
135	24-Aug-13		West	Maycock's Reef		13.295256	-59.664381		332	569		
136	24-Aug-13		West	Maycock's Reef		13.295256	-59.664381		274	376		
137	24-Aug-13		West	Maycock's Reef		13.295256	-59.664381		154	36		
138	25-Aug-13		West	Brightledge					159	55		
139	25-Aug-13		West	Brightledge					136	45		
140	25-Aug-13		West	Brightledge					144	50		
141	25-Aug-13		West	Brightledge					183	88		
142	25-Aug-13		West	Brightledge					137	44		
143	25-Aug-13		West	Great Ledge					160	56		
144	25-Aug-13		South	S Bridgetown port					137	45		
145	25-Aug-13		South	S Bridgetown port					162	56		
146	25-Aug-13		South	S Bridgetown port					160	54		
147	27-Aug-13		South	Old Fort Reef				12.3	100	33		
148	30-Aug-13		West	Great Ledge					273	361		
149	30-Aug-13		South	Carlisle Bay		13.088421	-59.613622		180	87		
150	30-Aug-13		South	Carlisle Bay		13.088421	-59.613622		182	78		
151	31-Aug-13		South	Foul Ground				24.6	181	62		
152	1-Sep-13		West	Dottin's		13.182431	-59.644139		137	45		
153	1-Sep-13		West	Dottin's		13.182431	-59.644139		152	59		
154	1-Sep-13		West	Dottin's		13.182431	-59.644139		142	49		
155	1-Sep-13		West	Dottin's		13.182431	-59.644139		146	51		

Fish ID	Date	Observer Category	Coast	Site name	Habitat	Latitude	Longitude	Depth (m)	Total Length (cm)	Weight (g)	Sex	Maturity stage
156	1-Sep-13		West	Dottin's		13.182431	-59.644139		162	60		
157	1-Sep-13		West	Dottin's		13.182431	-59.644139		142	48		
158	1-Sep-13		West	Dottin's		13.182431	-59.644139		156	53		
159	1-Sep-13		West	Dottin's		13.182431	-59.644139		141	44		
160	1-Sep-13		West	Dottin's		13.182431	-59.644139		150	52		
161	1-Sep-13		West	Dottin's		13.182431	-59.644139		141	43		
162	1-Sep-13		South	Carlisle Bay		13.088421	-59.613622	0.0	182	84		
163	1-Sep-13		West	Cement Plant Jetty		13.284229	-59.652795	18.5	272	335		
164	1-Sep-13		South	Graeme Hall Shallows		13.064216	-59.579158		158	55		
165	1-Sep-13		South	Graeme Hall Shallows		13.064216	-59.579158		165	60		
166	1-Sep-13		South	Graeme Hall Shallows		13.064216	-59.579158		152	54		
167	1-Sep-13		South	Graeme Hall Shallows		13.064216	-59.579158		170	57		
168	1-Sep-13		South	Graeme Hall Shallows		13.064216	-59.579158		179	61		
169	1-Sep-13		South	Graeme Hall Shallows		13.064216	-59.579158		166	48		
170	1-Sep-13		South	Graeme Hall Shallows		13.064216	-59.579158		147	40		
171	1-Sep-13		South	Graeme Hall Shallows		13.064216	-59.579158		135	33		
172	1-Sep-13		South	Surfer's Point				21.6	293	417		
173	1-Sep-13		South	Surfer's Point				21.6	316	575		
174	1-Sep-13		South	Surfer's Point				21.6	288	450		
175	16-Sep-13								170	56		
176	16-Sep-13								188	68		
177	16-Sep-13								166	55		
178	16-Sep-13								169	59		
179	16-Sep-13								177	69		
180	16-Sep-13								160	51		
181	16-Sep-13								181	77		
182	16-Sep-13								174	67		
183	16-Sep-13								170	61		
184	16-Sep-13								124	36		

Fish ID	Date	Observer Category	Coast	Site name	Habitat	Latitude	Longitude	Depth (m)	Total Length (cm)	Weight (g)	Sex	Maturity stage
185	16-Sep-13								255	227		
186	16-Sep-13								180	70		
187	16-Sep-13								139	43		
188	16-Sep-13								147	47		
189	Sep-13	SCUBA diver	East	Ragged Point	patch			25.9	307	411		
190	Sep-13								322	529		
191	Sep-13								250	253		
192	Sep-13								332	542		
193	Sep-13								275	286		
194	3-Sep-13		South	Oistins					251	245		
195	3-Sep-13		South	Oistins					214	169		
196	4-Sep-13		South	Gemswick					245	254		
197	4-Sep-13		South	Gemswick					180	74		
198	5-Sep-13		North	Animal Flower Cave	patch			16.1	314	423		
199	7-Sep-13	SCUBA diver	East	Ragged Point	patch			21.3	166	61		
200	7-Sep-13	SCUBA diver	East	Ragged Point	patch			21.3	137	37		
201	7-Sep-13	SCUBA diver	East	Ragged Point	patch			21.3	122	27		
202	9-Sep-13		South	Foul Ground				24.6	308	516		
203	9-Sep-13		South	Long Beach					265	259		
204	9-Sep-13		South	Long Beach					180	71		
205	9-Sep-13		South	Long Beach					166	53		
206	9-Sep-13								285	305		
207	9-Sep-13								270	257		
208	9-Sep-13								256	227		
209	9-Sep-13								178	74		
210	9-Sep-13								147	41		
211	10-Sep-13	SCUBA diver	East	Tent Bay				19.8	264	277		
212	10-Sep-13	SCUBA diver	East	Tent Bay				19.8	310	480		
213	10-Sep-13	SCUBA diver	East	Tent Bay				19.8	246	207		

Fish ID	Date	Observer Category	Coast	Site name	Habitat	Latitude	Longitude	Depth (m)	Total Length (cm)	Weight (g)	Sex	Maturity stage
214	11-Sep-13	SCUBA diver	East	Consett Bay	patch	13.184757	-59.46594	27.4	177	72		
215	11-Sep-13	SCUBA diver	East	Consett Bay	patch	13.184757	-59.46594	21.3	307	411		
216	11-Sep-13	SCUBA diver	East	Consett Bay	patch	13.184757	-59.46594	27.4	132	29		
217	11-Sep-13	SCUBA diver	East						322	529		
218	11-Sep-13	Spear fisher	East	Consett Bay		13.184757	-59.46594		250	253		
219	12-Sep-13	trap fisher	East	Glenburnie	fish pot			57.9	332	542		
220	12-Sep-13	SCUBA diver	East	Goat Hill Point	patch			21.9	275	286		
221	13-Sep-13	SCUBA diver	East	Tent Bay	patch			18.2	145	40		
222	13-Sep-13		East	Tent Bay				18.2	232	267		
223	13-Sep-13	SCUBA diver	East	Tent Bay				18.2	302	446		
224	15-Sep-13								282	329		
225	15-Sep-13								277	312		
226	15-Sep-13		East	Consett Bay		13.184757	-59.46594		321	432		
227	19-Sep-13		East	Ragged Point					110	9		
228	19-Sep-13	SCUBA diver	East	Ragged Point	patch			21.3	259	249		
229	19-Sep-13	SCUBA diver	East	Ragged Point	patch			21.3	182	89		
230	20-Sep-13		East	Bath					127	52		
231	20-Sep-13		East	Bath					299	432		
232	11-Sep-13		East	Consett Bay		13.184757	-59.46594		306	381		
233	19-Sep-13		East	Ragged Point					142	47		
234	23-Sep-13	SCUBA diver	East	Ragged Point	bank reef	13.09.257	059.28.841	21.3	320	605		
235	23-Sep-13		East	Ragged Point	bank reef				258	275		
236	25-Sep-13								167	59		
237	25-Sep-13								161	53		
238	25-Sep-13								289	406		
239	29-Sep-13								198	95		
240	29-Sep-13								244	250		
241	29-Sep-13								190	103		
242	J-A-S 2013	SCUBA diver							164	58.1		

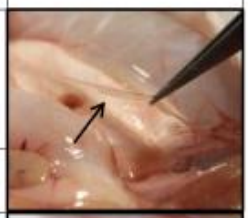
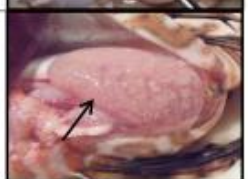
Fish ID	Date	Observer Category	Coast	Site name	Habitat	Latitude	Longitude	Depth (m)	Total Length (cm)	Weight (g)	Sex	Maturity stage
243	J-A-S 2013	SCUBA diver							344	501.2		
244	J-A-S 2013	SCUBA diver							161	48.1		
245	J-A-S 2013	SCUBA diver							156	64.6		
246	J-A-S 2013	SCUBA diver							255	196.1		
247	J-A-S 2013	SCUBA diver							349	566.5		
248	J-A-S 2013	SCUBA diver							283	282.3		
249	J-A-S 2013	SCUBA diver							177	66.9		
250	J-A-S 2013	SCUBA diver							136	30		
251	J-A-S 2013	SCUBA diver							281	301.9		
252	J-A-S 2013	SCUBA diver							127	32.4		
253	J-A-S 2013	SCUBA diver							162	50.9		
254	J-A-S 2013	SCUBA diver							174	51.4		
255	J-A-S 2013	SCUBA diver							157	41.7		
256	J-A-S 2013	SCUBA diver							177	65.6		
257	J-A-S 2013	SCUBA diver							150	45.8		
258	J-A-S 2013	SCUBA diver							124	25.4		
259	J-A-S 2013	SCUBA diver							138	30.5		
260	J-A-S 2013	SCUBA diver							150	31.2		
261	J-A-S 2013	SCUBA diver							172	55.7		
262	J-A-S 2013	SCUBA diver							172	57.1		
263	J-A-S 2013	SCUBA diver							174	59		
264	J-A-S 2013	SCUBA diver							167	48		
265	J-A-S 2013	SCUBA diver							137	25.6		
266	J-A-S 2013	SCUBA diver							160	51.2		
267	J-A-S 2013	SCUBA diver							198	9		
268	J-A-S 2013	SCUBA diver								408		

NB: Gonad stage: Immature (I), Early developing (ED), Spawning capable (SC); Developing (D),Actively spawning (AS). After Green et al (2012)

APPENDIX 9 – Standard lionfish biological data forms

Lionfish ID	Date caught	Coast	Site	TL (mm)	SL (mm)	Weight (g)	Gape (mm)		Sex	Gonad stage	Fat (ml)	Otoliths (mm)	Finclip/gill /muscle	Dissector Name
							H	W						

NB: Gonad stage: Immature (I), Early developing (ED), Spawning capable (SC); Developing (D),Actively spawning (AS). After Green *et al.* 2012 (see Table below).

Fish length (TL)	Appearance	Gender	Stage description	Stage	Image
<180 mm	Gonads are oval masses, cream-pink in colour, with ratio of length:width less than 2.	Female	Additional information required to determine reproductive stage.	Immature (virgin) or Early Developing	See Immature or Early Developing
	Gonads elongated with ratio of length: width greater than 2.	Histology required to distinguish between male and female.	Clear, threadlike structures 1-3 mm in diameter and 5-10 mm in length. Immature ovaries are largely indistinguishable from immature testes.	Immature (virgin)	
>180 mm	Gonads elongated with ratio of length:width greater than 2.	Male	Testes appear threadlike; 1-3 mm in diameter and 5-10 mm in length.	Immature (virgin)	
			Testes appear as cream-colored with well-defined edges. Testes are typically not larger than 10 mm in diameter and 20 mm in length in the largest of specimens.	Spawning capable	
	Gonads are oval masses, cream-pink in colour, with ratio of length:width less than 2.	Female	Ovary is cream colored and round with no edges. Width may vary from 5 - 15 mm. Eggs not visible macroscopically. Ovary is more firm than during the Developing stage.	Early developing	
			Ovary cream colored with some pinkish portions. Eggs visible as small white spheres. Size may vary from a width of 15 mm to 30+ mm. No gelatinous mucus visible around periphery.	Developing	
			Ovary large with clear gelatinous mucus containing visible eggs peripheral to central stroma. Size may vary from a width of 15 mm to 30+ mm.	Spawning capable	
			Large number of clear eggs encompassed in gelatinous mucus visible along periphery of the ovary. Note: ovary wall is removed in picture.	Actively spawning	

APPENDIX 9 - continued….

Lionfish stomach contents data sheet

Lionfish ID	Stomach item ID	Size (mm)	Volume (ml)	Weight (g)	Digestion level (1-5)	Preserved?