Invasive Red Lionfish in Shallow Habitats of the Turks & Caicos Islands

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ABSTRACT

The distribution of invasive lionfish, *Pterois volitans*, in shallow habitats (< 1 m to 3 m depth) has been monitored around South Caicos, Turks & Caicos Islands (TCI) since the first sighting in November 2007. Lionfish appear to be significantly more abundant in seagrass rather than reef habitats. Moreover, the increase in density (estimated from catch per unit effort) increased significantly from 2009 to 2010 in seagrass, but not on shallow reefs. Within seagrass lionfish were found almost exclusively in blowout ledges. The size frequency distribution of lionfish captured in shallow habitats (n = 126) were compared to specimens caught by fishermen and SCUBA diving tourist operations (n = 809) from around the TCI as part of a government initiated competition. The locations of capture of these specimens were unknown, but was assumed to come from deeper predominantly reef habitats and were significantly larger than those caught in exclusively shallow habitats (16.7 cm SL +/- 4.3 SD versus 11.2 cm SL +/ - 4.6 SD). Whilst this may be partly attributable to different methods of capture, this may indicate ontogenetic shifts in habitat use.

KEY WORDS: Lionfish, invasive, seagrass, blowout

El Pez León Invasor en Hábitats Superficiales de Las Turks & Caicos Islands

Estudiemos la distribución del pez león invasor, *Pterois volitans*, en hábitats superficiales (< 1 m a 3 m) alrededor de South Caicos, Turks & Caicos Islands (TCI) desde la primera observación en noviembre 2007. Parece que el pez león es más abundante en pastos marinos que en arrecifes. Además, la densidad del pez león (estimada por captura por unidad de esfuerzo) aumentó significativamente de 2009 a 2010 en pastos marinos, pero aumentó significativamente en arrecifes. En pastos marinos los peces león fueron encontrados casi exclusivamente en los salientes formados por las raíces y rizomas de pastos marinos en paredes alrededor de parches sin vegetación. Comparemos la distribución de las frecuencias de tallas de los peces león atrapados en habitats superficiales (n = 126) con la distribución de los peces atrapados para un concurso iniciado por el gobierno de TCI (n = 809). Los sitios de las capturas del los peces del concurso fueron desconocidos, pero fueron atrapados por pescadores y compañías turisticas de bucear de SCUBA, y suponemos que los sitios fueron atrapodos en hábitats más profundos y predominantemente en arrecifes. Los peces león del concurso fueron significativamente más grandes que los de hábitats superficiales (16.7 cm SL +/- 4.3 SD versus 11.2 cm SL +/- 4.6 SD). Aunque métodos distintos de atrapar los peces pueden explicar la diferencia en las tallas, tambien puede ser explicada por un cambio ontogenético del uso de habitat.

PALABRAS CLAVE: Pez león, invasión, pastos marinos, blowout

Rascasses Volantes Invasives en Eau Peu Profondes des Îles Turks & Caicos

La distribution de la rascasse volante invsasive, *Pterois volitans*, en eau peu profondes (<1 m à 3 m) est surveillée autour de South Caicos, les Îles Turks & Caicos (TCI) depuis la première observation en novembre 2009. Il parait que les rascasses volantes préférent les herbiers marins que le récif. De plus, la densité (estimé par CPUE) a augmenté significativement de 2009 à 2010 dans les herbiers mais pas dans les récifs peu profonds. Dans les herbiers les rascasses volantes se sont trouvés presque exclusivement dans les saillies formées par les racines et rhizomes dans les zones sans vegetation. La distribution des fréquences des tailles des rascasses volantes attrapées dans l'eau peu profondes (n = 126) était comparée avec la distribution des individus attrapés par pêcheurs et par sociétés de plongée SCUBA touristes (n = 808) autour de TCI pour un concours commencé par le gouvernement. Les emplacements de prise des ces individus étaient inconnus, mais on a suppose qu'ils étaient des habitas plus profonds et principalement des récifs, et ces individus étaient significativement plus grands que les rascasses volantes attrapées dans eau peu profondes (16.7 cm SL +/- 4.3 SD versus 11.2 cm SL +/- 4.6 SD). Bien qu'on puisse expliquer ce résultat avec la difference entre les méthodes de prise, peut-être ce résultat montre un change ontogénétique de l'utilisation d'habitat.

MOTS CLÉS: Rascasse volante, invasion, herbiers marins, blowout

INTRODUCTION

The introduction of red lionfish, *Pterois volitans/miles* (Scorpaenidae), into the western Atlantic has led to the fastest invasion documented for a marine fish (Morris et al. 2009). The success of the invasion is attributable to the qualities of the habitats invaded, as well as to the characteristics of the lionfish themselves. Widespread overfishing and habitat degradation have reduced densities of species that are ecologically equivalent to the red lionfish (i.e. general piscivores) and thus a niche has been available for the lionfish to exploit. The red lionfish has been able to outcompete native species because of its rapid growth, high and frequent reproductive output (Morris 2009), and venomous spines that effectively exclude most predators (Bernadsky and Goulet 1991), although predation has been witnessed (Maljković et al. 2008). Whilst both *P. volitans* and *P. miles* have been documented on the east coast of the U.S.A., only *P. volitans* is

believed to have extended its range south through the Bahamas, Turks and Caicos Islands (TCI), and the Caribbean (Freshwater et al. 2009). The potential ecological, economic and social implications of this invasion are an enormous concern for fishermen, natural resource managers, and conservationists alike. However, the consequences of lionfish in their introduced range are yet to be fully understood.

Much of our understanding of the red lionfish invasion of the tropical western Atlantic has been shaped by volunteer efforts. This has effectively mobilized a far larger workforce covering a broader range of locations than otherwise possible. However, as a result, effort is biased towards recording observations or collecting specimens using SCUBA within recreational diving limits. Less frequented shallower habitats have been largely overlooked. The nursery function of such habitats (e.g. seagrass beds and mangrove areas) are well documented (Heck et al. 2003, Mumby et al. 2004, Nagelkerken 2000) and thus the impact of invasion into these habitats is a serious concern.

The TCI consists of a small group of islands whose economy is dependent on tourism and fisheries. The first documented observations of lionfish were made in 2006 off Providenciales and West Caicos (Schofield 2009). However, they were not observed around South Caicos, the centre of fishing activities, until 2007 (Claydon et al. 2009). In November 2009, the TCI government initiated a tournament to encourage the capture of lionfish and many fishermen and tourist operations started catching lionfish and presenting their specimens to the Department of Environment and Coastal Resources. Details of where these individuals were caught (i.e. location, habitat and depth) were not recorded. However, the majority were caught by fishermen whilst free-diving for lobster of reef fishes and by tourist operations whilst SCUBA diving. Thus, it is believed that these lionfish were caught in predominantly reef habitats at depths ranging from several metres and extending to recreational SCUBA diving limits. The TCI lionfish tournament was part of several initiatives to help raise public awareness of the issue of the invasion, whilst also strengthening control efforts and providing many hundreds of specimens for research.

The aims of the study were to determine the extent to which lionfish use shallow habitats around South Caicos, TCI and to compare the size of specimens caught in these habitats to those that were caught in deeper water as part of the government competition.

METHODS

Study Area

The TCI are a group of small limestone islands spread between two shallow banks situated at the southern end of the Bahamian archipelago (Figure 1). South Caicos (N 21°29' W71°31') is located at the eastern edge of the Caicos Bank, a shallow platform (1 to 5 m) with areas that become exposed at low tide. Fringing mangroves, seagrass beds, and sandflats are predominant along the western shoreline of South Caicos. Extensive seagrass meadows and shallow patch reefs characterize the east and south coasts of the island where mangroves are largely absent. Deeper coral reefs line the edge of the bank as it drops down to > 2000 m.

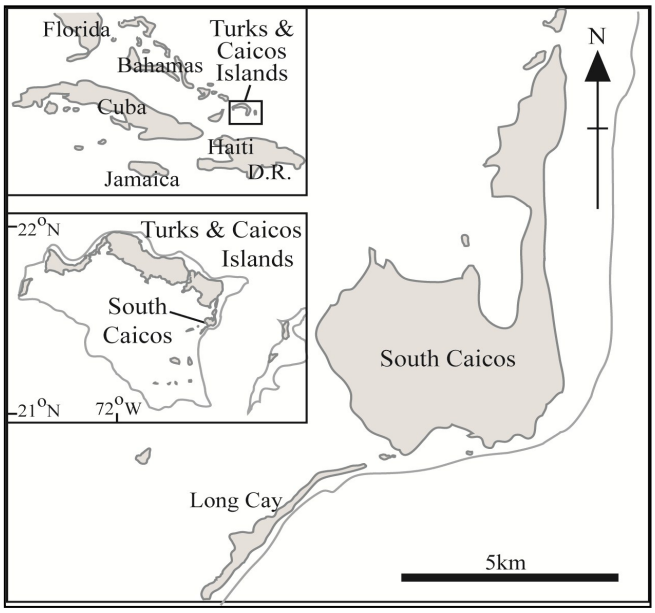

Figure 1. South Caicos (N 21°29' W71°31'), TCI.

Opportunistic Sightings

From August 2007 to July 2008 sightings of lionfish were recorded opportunistically around South Caicos. During this period, lionfish were not actively searched for, but documented when seen during snorkelling and SCUBA diving activities conducted from The School for Field Studies, Center for Marine Resource Studies. Although not quantified, effort was spread between snorkelling in seagrass, reef, and mangrove habitats and SCUBA diving on reefs between 15 to 30 m. Where possible lionfish were captured and standard lengths were measured to the nearest mm.

Systematic Sampling

Systematic sampling was conducted over two weeks in November 2009 and two weeks in April 2010. Searches for lionfish were focussed within separate sites of either reef, seagrass, or mangrove habitats less than 3 m deep around South Caicos. All observations were made on snorkel. The time spent searching at each site, the number of people searching, and the number of lionfish observed was used to calculate catch per unit effort (CPUE) as the number of lionfish seen per person per hour. When possible lionfish were captured using hand nets and their standard lengths were measured.

Tournament Specimens

In November 2009, the TCI government initiated a tournament to encourage the capture of lionfish. Specimens were caught by fishermen diving for lobster and reef fish and SCUBA dive tourist operations. From those caught, a total of 809 specimens were measured (standard length, cm). Although the location of capture was unknown, it was assumed that these lionfish represented a sample largely from reefs deeper than 3 m.

Statistical Analyses

Student's t-tests were used to compare the mean sizes of lionfish found on reefs with those found in seagrass habitats and the mean size of lionfish found in shallow habitats versus tournament specimens from deeper habitats. For both analyses, data were combined from opportunistic and systematic sampling. Chi^2 tests were used to test whether the frequency of sightings between reef and seagrass differed and whether the frequency of sightings increased significantly in reef and seagrass habitats from 2009 to 2010.

RESULTS

Opportunistic Sampling

The first lionfish was seen around South Caicos in shallow water in November 2007. Since then, the number of sightings per month in shallow habitats increased exponentially until the end of sampling in July 2008, with a total of 28 lionfish observed (Figure 2). Sightings in deeper habitats differed substantially with no lionfish seen in any month except for a single specimen in June 2008. This difference cannot be attributed to disparity in effort between deep and shallow habitats because the single sighting represents one lionfish in over sixteen km of transect conducted for a separate study on groupers (Claydon Unpub. data), and at this time substantially greater effort was expended in deeper habitats.

Systematic Sampling

Lionfish were observed in shallow reef (n = 4), seagrass (n = 60) and mangrove (n = 43) habitats, with CPUE of 0.20, 0.37 and 0.82 lionfish seen per person per hour respectively. Mangrove areas were under sampled and thus excluded from further analysis. The CPUE of lionfish was significantly higher in seagrass than reef (Chi^2 test: $Chi^2 = 7.41$, df = 1, $p < 0.05$; Figure 3). There was no significant difference in the mean size of lionfish in reef and seagrass habitats (Student's t-test: t = 0.024, df = 85.74, $p > 0.05$). CPUE increased significantly from 2009 to 2010 within seagrass habitats (Chi^2 test: $Chi^2 = 11.16$, df = 1, $p < 0.05$), but not within reefs (Chi^2 test: $Chi^2 = 0.09$, df = 1, $p > 0.05$). In seagrass habitats, 91% of lionfish were observed sheltering in blowout areas with 84% of these resting on or under ledges formed by exposed roots and rhizomes.

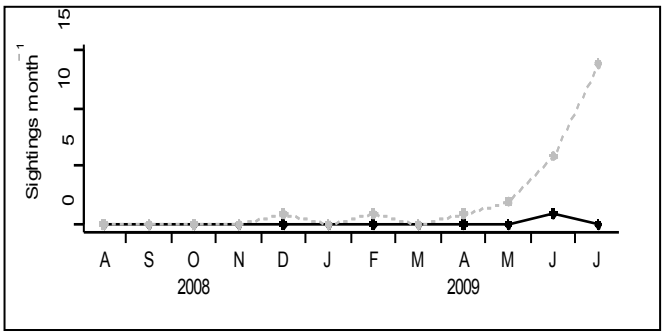

Figure 2. Opportunistic sightings of lionfish around South Caicos, TCI. Grey dots and line represents sightings in shallow habitats (< 3 m) and black represents sightings in

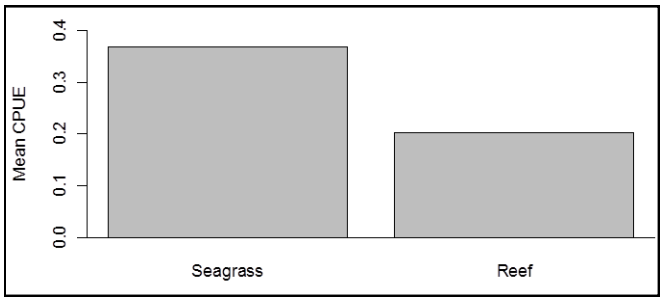

Figure 3. Mean CPUE (lionfish seen per person per hour) within shallow seagrass and reef habitats. Replicate surveys within habitats were of different duration and with differing numbers of observers. Therefore the means were calculated from totalling all effort within a habitat and all the lionfish observed. Thus no error bars are given. CPUE is significantly higher in seagrass than reef habitats ($p < 0.05$).

Size With Depth

There was substantial overlap in the size frequency distributions of lionfish caught in shallow habitats and those caught for the government sponsored tournament. However, the mean size of shallow specimens was significantly smaller than the deeper specimens from the government tournament (11.2 cm SL +/- 4.6 SD versus 16.7 cm SL +/- 4.3 SD, respectively; Student's t-test: t = 12.41, df = 161, $p < 0.05$; see Figure 4).

DISCUSSION

Lionfish were found in a variety of shallow habitats around South Caicos including reefs, seagrass beds and mangroves. This is consistent with observations in other locations (Barbour et al. 2010, Schofield 2009). However, the relative density of lionfish was almost twice as high in seagrass as opposed to reefs of similar depths. This is surprising for a species considered to be associated more with reef and rocky habitats in its native range (Schultz 1986), but lower densities on reefs compared to non-reef habitat has also been observed in San Salvador, Bahamas, where lionfish were more abundant in mangroves than reefs (Barbour, Montgomery, Adamson, Díaz-Ferguson

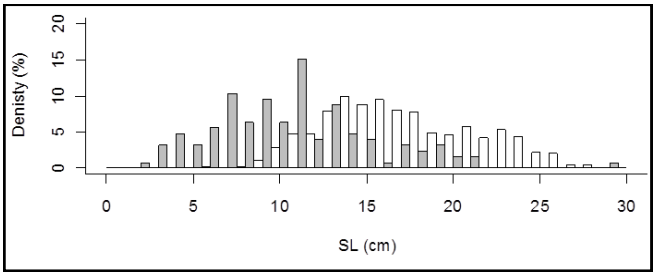

Figure 4. Size frequency distribution of lionfish caught in shallow habitats (< 3 m; grey bars) and those caught from deeper habitats (> 3 m; white bars). The mean size of lion-

and Silliman 2010). The extent to which lionfish inhabit mangrove habitats around South Caicos was hard to estimate from the present study, because, unlike the more extensive sampling in reefs and seagrass, searches focussed on a single small area of mangroves and may not be representative of its distribution in general.

In shallow waters around South Caicos, and the TCI in general, seagrass covers a substantially greater area than reefs and thus its importance as a habitat for lionfish should not be underestimated. Within seagrass beds, lionfish were observed almost exclusively in association with blowout areas. Around South Caicos, these are also preferred shelter sites for the regionally endangered Nassau grouper, *Epinephelus striatus*, where they are found ranging in size from those recently settled (Claydon and Kroetz 2008) to late stage juveniles (Claydon Unpubl. data). Lionfish may exert further pressure on Nassau grouper through competition for prey and shelter (Claydon, Calosso and Jacob 2009) [as has been suggested within mangrove habitats (Barbour, Montgomery, Adamson, Díaz -Ferguson and Silliman 2010)] and through directly preying upon groupers, the latter being documented elsewhere, albeit at low frequencies (Morris 2009, Morris and Akins 2009, Morris and Whitfield 2009). However, to an unknown extent, Nassau groupers have also been documented preying upon lionfish (Maljković, Van Leeuwen and Cove 2008), and thus the consequences of their overlapping preferences in shelter is difficult to predict for either species.

The mean size of lionfish differed significantly between those found in shallow and deeper habitats. In addition, there was a delay of approximately seven months between the first sighting of lionfish in shallow water and the first deeper sighting. Thus, the invasion of lionfish appears to fit a pattern whereby individuals settle in shallow habitats of seagrass, mangrove and reef and then move to deeper reef areas when they are larger. Such ontogenetic migration is well-known in fishes that are found as adults on reefs (Heck, Hays and Orth 2003, Mumby, Edwards, Arias-González, Lindeman, Blackwell, Gall, Gorczynska, Harborne, Pescod, Renken, Wabnitz and Llewellyn 2004, Nagelkerken 2000), but has not been described previously for lionfish in their invasive or native ranges.

Although the mean size of lionfish on shallow reefs was larger than those found in seagrass, this difference was not significant and evidence for habitat differentiation with size amongst shallow habitats was thus inconclusive. However, such a habitat separation with size has been observed between lionfish in mangroves and shallow reefs in San Salvador, the Bahamas (Barbour, Montgomery, Adamson, Díaz-Ferguson and Silliman 2010). Therefore, further research is likely to uncover subtleties in the patterns of lionfish distribution with distinct habitats being more representative of recently settled individuals, early juveniles and late juveniles, as has been described for other fishes such as the Nassau grouper, *Epinephelus striatus*, (Dahlgren and Eggleston 2000, Dahlgren and Eggleston 2001, Eggleston 1995) and the bluestriped grunt, *Haemulon striatus* (Mumby, Edwards, Arias-González, Lindeman, Blackwell, Gall, Gorczynska, Harborne, Pescod, Renken, Wabnitz and Llewellyn 2004).

The present study has shown that lionfish used a variety of shallow habitats around South Caicos, but were most abundant in seagrass. Despite evidence supporting ontogenetic migration, it is unknown what proportion of adults found on deeper reefs settled directly to these habitats and what proportion settled in shallow habitats prior to migrating. However, research involving tagging and otolith microchemistry could attempt to answer these questions. A more comprehensive understanding of habitat use by lionfish in its invasive range has important implications for management and control efforts.

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LITERATURE CITED

Barbour, A.B., M.L. Montgomery, A.A. Adamson, E. Díaz-Ferguson and B.R. Silliman. 2010. Mangrove use by the invasive lionfish *Pterois volitans*. *Marine Ecology Progress Series* **401**:291-294.

Bernadsky, G. and D. Goulet. 1991. A natural predator of the lionfish *Pterois miles*. *Copeia* **1991**:230-231.

Claydon, J.A.B. and A.M. Kroetz. 2008. The distribution of early juvenile groupers around South Caicos, Turks and Caicos Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute* **60**:345-350.

Claydon, J.A.B., M.C. Calosso, and S.E. Jacob. 2009. The red lionfish invasion of South Caicos, Turks & Caicos Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute* **61**:400-402.

Dahlgren, C.P. and D.B. Eggleston. 2000. Ecological processes underlying ontogenetic habitat shifts in a coral reef fish. *Ecology* **81**:2227-2240.

Dahlgren, C.P. and D.B. Eggleston. 2001. Spatio-temporal variability in abundance, size and microhabitat associations of early juvenile Nassau grouper *Epinephelus striatus* in an off-reef nursery system. *Marine Ecology Progress Series* **217**:145-156.

Eggleston, D.B. 1995. Recruitment in Nassau grouper *Epinephelus striatus*: post-settlement abundance, microhabitat features, and ontogenetic habitat shifts. *Marine Ecology Progress Series* **124**:9-22.

Freshwater, D.W., A. Hines, S. Parham, A. Wilbur, M. Sabaoun, J. Woodhead, L. Akins, B. Purdy, P.E. Whitfield, and C.B. Paris. 2009. Mitochondrial control region sequence analyses indicate dispersal from the US East Coast as the source of the invasive Indo-Pacific lionfish *Pterois volitans* in the Bahamas. *Marine Biology* **10**:1163-1168.

Heck, K.L., G. Hays, and R.J. Orth. 2003. Critical evaluation of the nursery role hypothesis for seagrass meadows. *Marine Ecology Progress Series* **253**:123-136.

Maljković, A., T.E. Van Leeuwen, and S.N. Cove. 2008. Predation on the invasive red lionfish, *Pterois volitans* (Pisces: Scorpaenidae), by native groupers in the Bahamas. *Coral Reefs* **27**:501.

Morris, J.A. 2009. *The Biology and Ecology of the Invasive Indo-Pacific Lionfish.* Ph.D. North Carolina State University, Raleigh, North Carolina USA.

Morris, J.A. and J.L. Akins. 2009. Feeding ecology of invasive lionfish (*Pterois volitans*) in the Bahamian archipelago. *Environmental Biology of Fishes* **86**:389-398.

Morris, J.A. and P.E. Whitfield. 2009. Biology, ecology, control and management of the Invasive Indo-Pacific lionfish: an updated integrated assessment. *NOAA Technical Memorandum NOS NCCOS* **99**:57.

Morris, J.A., J.L. Akins, A. Barse, D. Cerino, D.W. Freshwater, S.J. Green, R.C. Muñoz, C. Paris, and P.E. Whitfield. 2009. Biology and ecology of the iInvasive lionfishes, *Pterois miles* and *Pterois volitans*. *Proceedings of the Gulf and Caribbean Fisheries Institute* **61**:1-6.

Mumby, P.J., A.J. Edwards, J.E. Arias-González, K.C. Lindeman, P.G. Blackwell, A. Gall, M.I. Gorczynska, A.R. Harborne, C.L. Pescod, H. Renken, C.C.C. Wabnitz, and G. Llewellyn. 2004. Mangroves enhance the biomass of coral reef fish communities in the Caribbean. *Nature* **427**:533-536.

Nagelkerken, I. 2000. Importance of mangroves, seagrass beds and the shallow coral reef as a nursery for important coral reef fishes, using a visual census technique. *Estuarine, Coastal and Shelf Science* **51**:31-44.

Schofield, P.J. 2009. Geographic extent and chronology of the invasion of non-native lionfish (*Pterois volitans* Linnaeus 1758] and *P. miles* [Bennett 1828]) in the Western North Atlantic and Caribbean Sea. *Aquatic Invasions* **4**:473-479.

Schultz, E.T. 1986. *Pterois volitans* and *Pterois miles*: two valid species. *Copeia* **1986**:686-690.