

Spring 2014, Topic 4 --

What Should be Done to Slow the Spread of the Invasive Red Lionfish to North Carolina Waters?

BIOL 5680/CRM 7011 Current Topics in Coastal Biology

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| Author | Page |
|--------------------------|------|
| Adme, Zaneta (10, 5) | 1 |
| Bailey, Taylor (10, 5) | 5 |
| Burch, Amber (6,9) | 8 |
| Byrd, Cory (8,7) | 11 |
| Foote, Dustin (0,15) | 15 |
| Green, Olivia (11,4) | 19 |
| Jones, Andrew (12,3) | 22 |
| Quarles, Haley (11,4)) | 27 |
| Rose, Meganne (2,13) | 29 |
| Sassano, Nina (5,10) | 32 |
| Sharp, Amanda (10, 5) | 35 |
| Summerlin, Brandi (11,4) | 40 |
| Tobin, Travis (10,5) | 44 |
| Vu, Adrian (10,5) | 47 |
| Ward, Takeisha (10, 5) | 50 |
| Wells, Brenna (10,5) | 53 |

Zaneta Adme

*Albins, M. A., & Hixon, M. A. 2013. Worst case scenario: potential long-term effects of invasive predatory lionfish (*Pterois volitans*) on Atlantic and Caribbean coral-reef communities. *Environmental Biology of Fishes* 96(10-11):1151-1157.

The authors describe a “worst case scenario” situation to assess what will happen to coral reef communities if lionfish are allowed to continue to populate the reefs. The authors believe that the lionfish invasion will be limited by starvation or by a combination of pathogens, parasites, predators, and competitors to control the abundance of lionfish. The authors also discuss management actions that could be taken to minimize the effects of lionfish.

Anguillanews.com. 2014. Lionfish now served in Anguilla’s restaurants. Anguilla Times. Available: <http://www.anguillanews.com/enews/index.php/permalink/4776.html>. Accessed: 4/13/2014.

Anguilla has created a series of public education and awareness campaigns to promote the consumption of lionfish. The island has seen an increase of the number of restaurants serving the fish. The campaigns were facilitated by Anguilla’s Department of Environment and the Department of Fisheries and Marine resources in collaboration with the Anguilla Hotel and Tourism Association. The agency used the strategy of making the fish a targeted species and encouraged restaurants to put lionfish on their menus.

Apalachtimes.com. 2014. A big little victory against lionfish. The Apalachicola Times. Available: <http://www.apalachtimes.com/a-big-little-victory-against-lionfish-1.297887>. Accessed: 4/13/2014.

This article accounts the story of a fisherman that caught a lionfish on a hook by using shrimp as bait. The article talks about the increase in hook and line harvesting of the fish and lends itself to the possibility of hook and line being an option to control the population of the fish.

Finighan, G. 2014. A call to arms to fight against invading lionfish. The Royal Gazette, Bermuda. Available: <http://www.royalgazette.com/article/20140404/NEWS/140409870>. Accessed: 4/13/2014.

The Bermuda Lionfish Taskforce is asking residence help fight against the lionfish around Bermuda. The taskforce wants groups of volunteers to help hunt the fish. The taskforce has created a control plan centered on spearfishing and trapping the fish in deep water. They hope to train at least 1,000 volunteers in spearing and handling of the fish.

*Gallagher, S. E. 2013. Establishing a culinary market for lionfish species through a market-based organization to mitigate the environmental impacts of the invasive species. Doctoral dissertation. College of Charleston, Charleston, South Carolina.

The author analyzes the response to date of the federal government to invasion of lionfish in the Atlantic which the author sees as inefficient because of its inability to promote the public marketing of lionfish. The author believes that the creation of a NGO can properly tackle the marketing and educational outreach needed to build a proper culinary market for lionfish.

Goldman, J. G. 2014. Hunting lionfish makes them harder to hunt, surprising nobody. I09.com. Available: <http://animals.io9.com/hunting-lionfish-makes-them-harder-to-hunt-surprising-1560889728>. Accessed: 4/13/2014.

The author contends that the hunting of lionfish is causing the fish to go into hiding. According to a new study that measured the behavior of reefs that had been subject to spearfishing and others that had not, lionfish on reefs that had been hunted on previously were better at hiding and that they were much less active during the day.

*Green, S. J., & Côté, I. M. 2009. Record densities of Indo-Pacific lionfish on Bahamian coral reefs. *Coral Reefs* 28(1):107-107.

The authors report that lionfish have rapidly spread through the Bahamas and northern Caribbean. They also report that densities of the fish have exceeded previously recorded densities in the area. They documented densities at 3 different sites at least 1 kilometer apart and found more than 390 lionfish per hectare.

*Green, S. J., Akins, J. L., Maljković, A., & Côté, I. M. 2012. Invasive lionfish drive Atlantic coral reef fish declines. *PLoS One* 7(3):e32596.

The authors use this report to document the response of native fish to predation by lionfish on nine coral reefs off of the Bahamas. They assessed the lionfish diet by analyzing the stomach contents and identified the changes in fish biomass through visual surveys. Over a six year period the lionfish biomass comprised almost 40% of the total biomass in the system while the biomass of the lionfish prey declined by 65%.

Hausheer, J. 2013. Creature feature: lionfish. *Oceana*. Available: <http://oceana.org/en/blog/2013/09/creature-feature-lionfish?gclid=CLXL9ejU4L0CFSSQ7AodlDoAnw>. Accessed: 4/13/2014

This article is used to introduce people to the lionfish problem. The article gives a brief background of the lionfish issue and informs readers of just how prevalent lionfish are now in the Atlantic. The author states that when lionfish arrive in a new reef in the Atlantic they can reduce the native population of the reef by up to 65%.

McFadden, D. 2014. Invasive lionfish on the decline In Jamaica after national campaign to save reefs. *Huffington Post*. Available: http://www.huffingtonpost.com/2014/04/14/lionfish-jamaica-invasive-species_n_5143460.html. Accessed: 4/14/2014.

The article reports on the decline in the lionfish population in the reefs around Jamaica. The author attributes the decline in population to the increase in the commercial market for lionfish. Jamaica's EPA reported a 66% drop in the lionfish population. The author states that after fisherman learned to handle the fish, the lionfish catch began to increase. The decrease has come primarily in shallow waters but coastal managers are hopeful that the increase in the use of the fish in markets can help keep the lionfish population under control in the shallow reefs.

O'Hara, T. 2014. Lionfish branded as enemy of the seas. Keynews.com. Available: <http://keynews.com/node/54703>. Accessed: 4/13/2014.

Several proposals are being introduced in Florida to help eradicate the lionfish population in Florida waters. One proposal would ban the importation of live lionfish and prohibit aquaculture of lionfish in Florida. Another proposal seeks to make it easier to hold a spearfishing tournament for lionfish by expediting the permitting process. The article also comments on increasing the commercial market for lionfish. One fisherman who sets lobster traps in deep water in excess of 100 feet caught 7,000 pounds of lionfish this past lobster season and 10,000 the year before.

*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(3):473-479.

The article seeks to explain the life history of two lionfish species in the Atlantic along with the extents to which they are found in the Atlantic. The author used the USGS Non-native Aquatic Species database to identify the locations where the two species have been located.

Soo, C. K. 2014. Vendors skeptical about lionfish. *Trinidad and Tobago Guardian*. Available: <http://guardian.co.tt/news/2014-03-16/vendors-sceptical-about-lionfish>. Accessed: 4/13/2014.

The author says that the biggest obstacle to getting people to eat lionfish is the misconception that the meat of the lionfish is poisonous. This leads to a general unwillingness to even try the fish. The author interviewed an expert that says the only way clear up the misconceptions education through the media.

Tbnweekly.com. 2014. Destructive lionfish growing in numbers. *Tampa Bay Weekly*. Available: http://www.tbnweekly.com/content_articles/040914_out-01.txt. Accessed: 4/13/2014.

This article chronicles the rapid increase of the red lionfish population in Tampa Bay. This is important because confirms recent evidence that the species can also invade estuarine systems. Lionfish are being found in brackish waters. R. Leroy Creswell of the University of Florida's Sea Grant Program says that lionfish currently present one the most important issues for fisheries.

Wadlow, K. 2014. State fisheries managers recommend further efforts to fight invasive lionfish. *Florida Keys Keynoter*. Available: <http://www.keynet.com/2014/04/12/496104/state-fisheries-managers-recommend.html>. Accessed: 4/13/2014.

The staff of the Florida Fish and Wildlife Conservation Commission wants the Florida Wildlife Commission to support measures that will allow more divers to kill lionfish. The new rules that are being proposed would allow divers to use rebreathers and create a permit to allow spearfishing of lionfish in areas where spearfishing is not permitted.

Taylor Bailey-Revised

Adamson, A. 08/19/10. REEF, Florida Keys National Marine Sanctuary to Host Inaugural Lionfish Derbies. Reef Environmental Education Foundation. <http://www.reef.org/node/4045> Accessed: 04/09/14

Florida Keys National Marine Sanctuary and Reef Environmental Education Foundation collaborated to hold a lionfish derby. Divers competed to spear lionfish or capture them via hand net and were eligible for more than \$10,000 in cash and prizes. Teams of four register to compete, paying a \$100 entry fee. Derbies are generally offered during the summer in various parts of Florida. These derbies are one way for scientist to get the public involved in trying to control the lionfish population.

*Aguilar-Perera, A. and A. Tuz-Sulub. 2010. Non-native, invasive Red lionfish (*Pterois volitans* [Linnaeus, 1758]:Scorpaenidae), is first recorded in the southern Gulf of Mexico, off the northern Yucatan Peninsula, Mexico. *Aquatic Invasions* 5(2):S9-S12.

This journal article describes the invasion of red lionfish and the involvement of the people. In 2009 pamphlets with information regarding lionfish was distributed to locals. Shortly after spear fisherman reported siting of this species. Specimens were collected for further research. Comparative analysis were made to lionfish found in other areas.

*Arias-Gonzalez, J., C. Gonzalez-Gandara, J. Cabrera, and V. Christensen. October 2011. Predicted impact of the invasive lionfish *Pterois volitans* on the food web of a Caribbean coral reef. *Environmental Research*. 111(7):917-925.

This journal describes the impact that lionfish have on the ecosystem. Lionfish have a very diverse diet and will eat almost anything. This is problematic, because it begins to deplete the local species. This causes a decrease in biodiversity, because depleting various species begins to work its way down the food web causing all aspects to be negatively affected. Management is required to prevent this. Studies show if lionfish were to be exploitable that the population could be maintained at a low level.

Barclay, C. 01/10/02. Lionfish Observed Off North Carolina. National Oceanic and Atmospheric Association. <http://www.publicaffairs.noaa.gov/releases2002/jan02/noaa02r105.html> Accessed: 04/08/14

This alert was sent out by the National Oceanic and Atmospheric Association after scuba divers spotted two lionfish off the coast of North Carolina near a shipwreck. The divers contacted the NOAA lab in Beaufort, NC who were able to send the species off to be positively identified by an expert. The lab warned that they fear lionfish would become much more frequently spotted off the coast. It was concluded that further research would be done to determine more information about this species whereabouts.

Beckel, T. 2010. Venomous Lionfish Invade South Florida Waters. Lionfish Hunters.
<http://www.lionfishhunters.org/> Accessed: 04/10/14

There have been 68 different invading species in Florida, the Caribbean, and the Gulf of Mexico over the past century. However, the lionfish has been deemed the most problematic. Their rapid population growth and lack of predators has made them almost unstoppable. If nothing is done, biodiversity will decrease and ecosystems, especially reef ecosystems, will be destroyed. This article advocated that research is needed to find the most efficient way to control this species.

*Cote, I., S. Green, and M. Hixon. August 2013. Predatory fish invaders: Insights from Indo-Pacific lionfish in the western Atlantic and Caribbean. *Biological Conservation* 164:50-61.

This journal goes into in depth information regarding lionfish. It discusses the invasion along with population distribution. It touches all aspects of life progression from the beginning of reproduction on through adulthood. It also describes mechanisms for breaking barriers and both the direct and indirect effect from this species. The article suggests making lionfish a targeted species in the fishery communities.

Gupta, A. 05/08/09. Invasion of the Lionfish. *Smithsonian*.
<http://www.smithsonianmag.com/science-nature/invasion-of-the-lionfish-131647135/?no-ist>
Accessed: 04/10/14

Genetic test show that as little as 3 lionfish may have been all that was released in 1992 that started this explosion. They lay hundreds of eggs and are able to reproduce after just 55 days during all times of year. In 2000, a diver spotted two lionfish off the coast of North Carolina, where the National Oceanic and Atmospheric Association began to monitor them. Today, lionfish have taken over the waters. This article expands on the history of lionfish progressing in US waters over the years. It also touches on management in the US. One man has created traps based off lobster traps in Bermuda. Other options include holding frying workshops to increase the demand for lionfish served in restaurants.

*Jud, Z., and C. Layman. March 15, 2012. Site fidelity and movement patterns of invasive lionfish, *Pterois* spp., in a Florida estuary. *Journal of Experimental Marine Biology and Ecology* 414-415:69-74.

Understanding the life stages of lionfish is important when prediction future population levels and the best way to manage them. This study tagged 55 lionfish at various life stages using different length measurements. The fidelity of the lionfish was then monitored. IT was determined that if lionfish could be targeted at the egg/larval stage that the population could be controlled. However, this would have to happen frequently due to rapid growth.

*Morris, J., Jr. (Ed.). 2012. Invasive Lionfish: A Guide to Control and Management. Gulf and Caribbean Fisheries Institute.

http://lionfish.gcfi.org/manual/InvasiveLionfishGuide_GCFI_SpecialPublicationSeries_Number_1_2012.pdf Accessed: 04/09/14

This manual gives all types of information regarding lionfish. It begins with information regarding invasion into the Atlantic, specifically U.S. waters and moves into information regard education, outreach, and management. Management is the primary focus of this article and describes various techniques to control this out of hand population.

National Oceanic and Atmospheric Association. 05/09/11. Lionfish Invade US Waters. Ocean Service NOAA. http://oceanservice.noaa.gov/education/stories/lionfish/lion02_invade.html Accessed: 04/08/14

This article goes into a short history about lionfish. Lionfish were spotted and finally confirmed off the coast of North Carolina in August of 2002 by divers at a local shipwreck. A year later 19 lionfish had been spotted off the coast and it is now estimated that between 2000 and 2003 there were a total of 49 spotted at 16 different shipwrecks. Scientists believe these species came to be in US waters from aquarium releases.

National Oceanic and Atmospheric Association. 11/29/11. Fileting the Lion. Ocean Service NOAA. <http://oceanservice.noaa.gov/news/weeklynews/june10/eatlionfish.html> Accessed: 04/09/14

The National Oceanic and Atmospheric Association suggest eating lionfish. Between 2004 and 2008 lionfish increased by 700 percent off North Carolina alone. They are dangerous to reef ecosystems and due to a chain reaction could potentially cause seaweed to overtake the reefs. NOAA has started an 'Eat Lionfish' campaign stating "If you can't beat them, eat them." The campaign began in June 2012 at the Smithsonian Institution's Savoring Sustainable Seafood reception in Washington, DC.

Pasko, S. 2005. Lionfish. Aquatic Nuisance Species Task Force. <http://www.anstaskforce.gov/spoc/lionfish.php> Accessed: 04/08/14

This website describes how the two most problematic species in U.S. waters are red lionfish and devilfish. It goes into further detail describing what lionfish look like and their body make up. It lists all know locations and a brief history of how these lionfish came to be in U.S. waters. The biggest problem with lionfish is that their diet includes a wide variety of over 40 species. This is problematic because it causes a decrease in biodiversity. The site briefly touched on management options such as encouraging divers and anglers to remove this species, as well as mentioning that lionfish are an edible species; however, no detailed options were available.

Schofield, P., J. Morris, Jr, J. Langston, and P. Fuller. 09/18/12. *Pterois volitans/miles*. USGS Nonindigenous Aquatic Species Database.

<http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=963> Accessed: 04/08/14

Lionfish are in the scorpion fish family and are related to devilfish. This article goes into specific information about the family and specific relatives. It also gives links for real time distribution maps. Information regarding the introduction of this species, impacts of introduction and ecology can be found. A brief management overview is given regarding the 2010 workshop held by the International Coral Reef Initiative.

Spencer, E. July 10, 2013. Lionfish: Got to Eat 'Em to Beat 'Em. National Geographic.

<http://newswatch.nationalgeographic.com/2013/07/10/lionfish-gotta-eat-em-to-beat-em/>

Accessed: 04/10/14

This article focuses on the restaurant aspect of managing lionfish. Creating a demand for them in the seafood industry will demand the capture causing a control in population explosion and an economic revenue flow. This site lists a couple of recommended recipes for those interested in trying lionfish.

Williams, N. December 07, 2010. Major Lionfish Hunt Launched. *Current Biology* 20(23):R1005-1006.

Because lionfish have become so problematic in US waters, scientists and other private organizations have begun promoting lionfish derbies to get the public involved and to decrease lionfish populations. In 2010 at on derby alone in Florida, 109 lionfish were caught. The Bahamas, which don't have nearly as many protective acts as Florida, have killed over 2000 lionfish in a span of just 2 years. The article states that lionfish will never be completely eradicated, but suggest that derbies and seafood markets are viable ways to manage this species.

Amber Burch

*Albins, M.A. and M.A. Hixon. 2013. Worst case scenario: potential long-term effects of invasive predatory lionfish (*Pterois volitans*) on Atlantic and Caribbean coral-reef communities. *Environmental Biology of Fishes* 96: 1151-1157. Available from:

<http://link.springer.com.jproxy.lib.ecu.edu/article/10.1007%2Fs10641-011-9795-1>. Accessed: 04/13/2014.

This study looks toward the future of lionfish where this invasive fish species will combine with the stressors that already contribute to marine life (like overfishing) to cause negative changes in coral reef communities. This study also looks at management possibilities that could reduce the long-term effects.

*Arias-Gonzalez, J.E., C. Gonzalez-Gandara, J.L. Cabrera, and V. Christensen. 2011. Predicted impact of the invasive lionfish *Pterois volitans* on the food web of a Caribbean coral reef.

Environmental Research 111: 917-925. Available from:

<http://www.sciencedirect.com.jproxy.lib.ecu.edu/science/article/pii/S0013935111001952>.

Accessed: 04/13/2014.

This study looks at the invasion of lionfish in the Caribbean, how their invasion has impacted the coral reef food-webs and ways that the number of lionfish can be lowered. It was determined that if all adult lionfish were vulnerable, it would be possible to fish lionfish to a low level. However, to keep the lionfish at low numbers, the fishing pressure would have to be maintained or the lionfish would recover quickly.

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

<http://jproxy.lib.ecu.edu/login?url=http://dx.doi.org/10.3354%2Fmeps08373>. Accessed:

04/13/2014.

Many studies have been conducted on coral reef communities, however this study looks at how lionfish use non-reef critical habitats. The stomach content of the lionfish was compared between those in non-reef habitats and coral reef habitats. The contents of stomach showed prey items that were conclusive that lionfish colonize and feed in mangrove habitats in the Bahamas.

*Green, S.J., J.L. Akins, A. Maljkovic, and I.M. Cote. 2012. Invasive Lionfish Drive Atlantic Coral Reef Fish Declines. PLoS One. Available from:

<http://search.proquest.com.jproxy.lib.ecu.edu/docview/1323964158>. Accessed: 04/13/2014.

This study focuses on the response of native fish communities to the predation of lionfish on coral reefs off of New Providence Island in the Bahamas. The results show that the lionfish abundance was correlated with a 65% decline in the biomass of the lionfish's prey of 42 different types of fish in two years.

Gupta, A. May 8, 2009. Invasion of the Lionfish. Smithsonian Magazine. Available from:

<http://www.smithsonianmag.com/science-nature/invasion-of-the-lionfish-131647135/?no-ist>.

Accessed: 04/14/2014.

This article gives the full backdrop of lionfish from when and how they (theoretically) came into Atlantic waters to when people began noticing their presence. It also gives information on the biology of lionfish.

Johnson, D.L. No Date. The ecological and socio-economic benefits of lionfish harvestation.

Rareplanet.com. Available from: <http://www.rareplanet.org/en/solution-search-entry/ecological-and-socio-economic-benefits-lionfish-harvestation>. Accessed: 04/14/2014.

This article discusses how the invasion of lionfish has affected fishing organizations along the coast of Quintana Roo, Mexico. It talks about three major categories based on

lionfish such as their biodiversity impact, the impact on human wellbeing and livelihoods, and the sustainability and resilience of lionfish.

Maurer, K. No Date. Diving Deep. Our State North Carolina. Available from: <http://www.ourstate.com/lionfish/>. Accessed: 04/14/2014.

This article talks about how lionfish have affected the coast of North Carolina from the coloring of the coral reefs to the disappearance of native fishes. Debby Boyce (a diver that is mentioned) first noticed this differences in 2005 and now recruits other divers to capture and kill lionfish in order to help preserve the waters off of North Carolina.

*Moonsammy, S., D. Buddo, and G. Seepersad. 2011. Assessment of the Economic Impacts of the Lion Fish Invasion in Jamaica. Available from: http://procs.gcfi.org/pdf/GCFI_64-13.pdf. Accessed: 04/13/2014.

This is the economic impact statement based on lionfish for the island of Jamaica. This document states that there are direct and indirect economic impacts caused by lionfish in areas of domestic fisheries, marine tourism and for maintaining the biodiversity.

*Moore, A. 2012. The Aquatic Invaders: Marine Management Figuring Fishermen, Fisheries, and the Lionfish in The Bahamas. *Cultural Anthropology* 27: 667-688. Available from: <http://onlinelibrary.wiley.com.jproxy.lib.ecu.edu/doi/10.1111/j.1548-1360.2012.01166.x/full>. Accessed: 04/13/2014

This article looks at fisheries anthropology through the attempts that have been made to incorporate lionfish as a commercial fish species in the Bahamian fishery. By analyzing the metaphoric of impact, it is shown how fishermen and lionfish are now considered to be “malleable cultural figures” in The Bahamas.

*Morris, J.A. 2009. The Biology and Ecology of the Invasive Indo-Pacific Lionfish. North Carolina State University. Available from: <http://repository.lib.ncsu.edu/ir/bitstream/1840.16/3983/1/etd.pdf>. Accessed: 04/14/2014.

This dissertation by James Morris in 2009 at NC State University talks about every possible aspect of the lionfish species. In this dissertation, the biology of lionfish, their feeding ecology, reproductive dynamics and management control methods are discussed.

*Mumby, P.J., A.R. Harborne, and D.R. Brumbaugh. 2011. Grouper as a Natural Biocontrol of Invasive Lionfish. *PLoS One*. Available from: <http://search.proquest.com.jproxy.lib.ecu.edu/docview/1304910710>. Accessed: 04/13/2014.

This study looks at how groupers can be used as a form of pest control against lionfish in the Caribbean region. The groupers were surveyed along a chain of reefs in the Bahamas, which also included a marine reserve that has the top one percentile of Caribbean grouper biomass. The results show that in relation to the biomass of grouper, lionfish biomass showed a 7-fold and non-linear reduction.

National Centers for Coastal Ocean Service. No Date. Invasive Species. Nation Oceanic and Atmospheric Administration. Available from:

<http://coastalscience.noaa.gov/research/pollution/invasive/>. Accessed: 04/13/2014.

This website written by the National Centers for Coastal Ocean Science (NCCOS) addresses the economic affects that invasive species cause. NCCOS estimate that because of the 50,000 exotic species, the US spends an average of \$138 billion per year in damages, losses and control measures.

*Pala, C. February 7, 2014. As Lionfish Invade, Divers Defend Threatened Ecosystems. Science 343: 591-592. Available from:

<http://www.sciencemag.org.jproxy.lib.ecu.edu/content/343/6171/591.full>. Accessed: 04/13/2014.

This article discusses how the release of lionfish into the Atlantic Ocean has caused a rapid removal of native fish species. Mentioned in this article is Pericles Maillis, a Bahamian conservationist, who (along with others) used ecological models to plan a 18-month “offensive approach” to the lionfish by successfully killing lionfish enough for 24 of the coral reefs near the Bahamas to rebound.

Reef Environmental Education Foundation. No Date. Lionfish Derbies. Reef.org. Available from: <http://www.reef.org/lionfish/derbies>. Accessed: 04/14/2014.

This website by the Reef Environmental Education Foundation is the sign up site for “lionfish derbies”. It also provides information on what a derby is as well as why these derbies are important for increasing awareness about lionfish.

Wilcox, C. July 1, 2013. The Worse Marine Invasion Ever. Slate.com. Available from: http://www.slate.com/articles/health_and_science/science/2013/07/lionfish_invasion_the_invasive_fish_are_eating_so_many_native_species_that.html. Accessed: 04/14/2014.

This article discusses how lionfish are the worse marine invasion to date in Atlantic waters because of their speed and ability to spread faster than any other invasive species. Wilcox also write about how lionfish are not just overweight, but so obese that they are showing signs of liver damage.

Cory Byrd

*Albins, M.A., and M. A. Hixon. 9/11/2008. Invasive Indo-Pacific lionfish *Pterois volitans* reduce recruitment of Atlantic coral-reef fishes. Marine Ecology Progress Series 367: 233-238.

Lionfish have become a problem along the Atlantic coast and in this journal article the authors address the problem of the invasive species Lionfish. Using controlled field experiments they examined the short-term effects of lionfish on the recruitment of native reef fish in the Bahamas. The results showed Lionfish to have a large impact on the native marine life and the environment they live in.

*Albins, M.A., and M.A. Hixon. 4/15/2011. Worst case scenario: potential long-term effects of invasive predatory lionfish (*Pterois volitans*) on Atlantic and Caribbean coral-reef communities. *Environmental Biology of Fishes* 96: 1151-1157.

This journal entry was done on the worst possible scenario that the lionfish could have on the environment and the native species that the lionfish consume. In this study they believe that the lionfish invasion will be limited either by the lionfish starving the worst end to the worst case scenario or by some combination of native pathogens, parasites, predators, and competitors controlling the abundance of lionfish. Since the introduction into the Atlantic Ocean the lionfish has become a top predator on the food web and this could mean a change in the way the food web looks.

*Barbour, A.B., M.L. Montgomery, A.A. Adamson, E. Diaz-Ferguson, B.R. Silliman. 2/22/2010. Mangrove use by the invasive lionfish *Pterois volitans*. *Marine Ecology Progress Series* 401: 291-294.

The *Pterois volitans* is an invasive species in the sub-tropic and tropical Western Atlantic. It is known that they have invaded many coral reef ecosystems, but it is unknown if they have inhabited any other marine ecosystems. This study was done to see if the Lionfish has invaded the mangroves of San Salvador in the Bahamas. The results show that they colonize and feed in these mangroves, due to abundance of food and lack of predators but further studies of lionfish outside reef habitat are required to understand the effects of this marine invasion.

*Clipperton, J. 2013. Lionfish of the Pteroinae. *UltraMarine Magazine* 41: 68-74.

There are many different types of Lionfish with many different names. Some are known as turkey fish, fire fish, and even devilfish, but they all fall within the subgenus Pteroinae. They are all voracious hunters with different behavior habits. This journal entry talks about six different types of Lionfish that are now common in the Atlantic Ocean, giving detailed behavior habits and pictures of the different types of Lionfish.

Florida Fish and Wildlife Conservation Commission. No Date. Lionfish- *Pterois volitans*. Myfwc.com Available: <http://myfwc.com/wildlifehabitats/nonnatives/marine-species/lionfish/> Accessed: 4/14/14

This website is about general information of lionfish and how they have taken over the coast of Florida. It gives a map with their native range and the distribution and range in Florida. There is also an impacts section and a description of the fish and what you should do if you see one in the wild. This website is mostly on lionfish in Floridian waters and the impacts it has had on Florida.

*Green, S.J., J.L. Akins, A. Maljkovic, I.M. Cote. 3/7/2012. Invasive Lionfish Drive Atlantic Coral Reef Fish Declines. *PLoS ONE* 7(3): e32596. Available:

<http://www.plosone.org/article/fetchObject.action?uri=info%3Adoi%2F10.1371%2Fjournal.pone.0032596&representation=PDF>

Lionfish are viscous predators and can have major negative impacts on the environment in which they live in. This research was done to the response of native fish communities to predation by lionfish populations on nine coral reefs off New Providence Island, Bahamas. Data was collected through stomach contents analysis and changes in fish biomass through visual surveys of lionfish and native fishes at the sites over time. The biomass showed that lionfish were nearly 40% of total predator biomass in the system and in just two years there was a 65% decline in the 42 Atlantic prey fish biomass.

Greenberg, P. No Date. Lionfish Invasion: A Guide to Hunting & Fishing. FoodandWine.com. Available: <http://www.foodandwine.com/articles/lionfish-invasion-a-guide-to-hunting-and-fishing> Accessed: 4/14/14.

This website addresses the problem of Lionfish but also has a section on creating a market for Lionfish. Lionfish-as-food promoters emphasize that the fish are venomous when they sting but not poisonous to consume (the venom is contained only within the fish's spines, not in its flesh). This could potentially create a market for these fish and help reduce Lionfish populations. The website also talks about the hunt for Lionfish. Greenberg talks about his experience catching Lionfish and how you can get involved to help reduce Lionfish populations.

*Kimball, M.E., J.M. Miller, P.E. Whitfield, J.A. Hare. 11/30/2004. Thermal tolerance and potential distribution of invasive lionfish (*Pterois volitans/miles* complex) on the east coast of the United States. Marine Ecology Progress Series 283: 269-278.

Lionfish enjoy warmer waters; this is why they thrive in the Caribbean and the sub-tropic zones on the eastern sides of North and South America. In the northern hemisphere lionfish are found no higher than Cape Hatteras due to the different currents that collide at Cape Hatteras. In the southern hemisphere they are not found as far south and this reason is unknown. Possible reasons for the constrained southern limit may include planktonic transport mechanisms, patterns of juvenile and adult movements, and the initial lionfish introduction site. This research was done to find the range limits of the invasive lionfish.

NOAA. No Date. Lionfish Fact Sheet. NOAA.gov. Available: http://www.habitat.noaa.gov/pdf/best_management_practices/fact_sheets/Lionfish%20Factsheet.pdf Accessed 4/14/14

This fact sheet has data on the lionfish and its native and nonnative ranges. Towards the end of the sheet is how NOAA is responding to the lionfish outbreak. NOAA is working with the Reef Environmental and Education Foundation (REEF) and the United States Geological Survey (USGS) to help get awareness of the outbreak and find ways to help remove lionfish off coastal reefs in the Atlantic Ocean.

Michael, S.W. No Date. Lionfish: Risky but Rewarding. FishChannel.com. Available: <http://www.fishchannel.com/media/saltwater-aquariums/species-info/lionfish/lionfish-rewards.aspx.pdf> Accessed: 4/14/14

There are many questions about Lionfish, like “How many species are there?” and “How venomous are Lionfish?” This website has answers to many questions like those. This website is to help people who want to own Lionfish in their home the risks versus the rewards. Although they are very beautiful fish they have very poisonous venom that has caused deaths, which is the biggest concern of owning these fish. Even though it is allowed to own these fish you should still think about the risk over the reward when purchasing them.

Morris, J.A., Jr. Whitfield, P.E. 2009. Biology, Ecology, Control and Management of the Invasive Indo-Pacific Lionfish: An Updated Integrated Assessment. NOAA. Available: http://aquaticcommons.org/2847/1/NCCOS_TM_99.pdf Accessed: 4/14/14.

This research was done looking at the environmental and economic impact of the invasive species lionfish. Invasive species such as lionfish are not just bad for the environment it is bad for the economy. Extreme economic costs have resulted from many invasions, e.g., Formosan termite, which causes an estimated \$300 million in damage annually in New Orleans alone. Recent estimates suggest that the cost of invasive species to the U.S. economy is \$137 billion annually. This pdf is a good source of information about the lionfish and what it could do to the economy and environment.

*Mumby, P.J., A.R. Harborne, D.R. Brumbaugh. 6/23/2011. Grouper as a Natural Biocontrol of Invasive Lionfish. PLoS ONE 6(6): e21510. Available: <http://www.plosone.org/article/fetchObject.action?uri=info%3Adoi%2F10.1371%2Fjournal.pone.0021510&representation=PDF>

Lionfish do not have many natural predators in the tropic and sub-tropic Atlantic Ocean. They are an invasive species and within just five years have invaded the majority of the Caribbean. Because of their poisonous spines not many fish can eat this fish but they have been found in the gut contents of large Caribbean groupers. While Caribbean grouper appear to be a biocontrol of invasive lionfish, the overexploitation of their populations by fishers, means that their median biomass on Caribbean reefs is an order of magnitude less than this study was capable of doing. The results of this study show that in order for grouper to become a stable solution for controlling the outbreak of lionfish, overfishing of grouper has to stop.

Schofield, P.J., J.A. Morris, J.N. Langston, P.L. Fuller. 9/18/2012. *Pterois volitans*/miles. USGS Nonindigenous Aquatic Species Database. Available: <http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=963> Accessed: 4/14/14.

This webpage analyzes two of the invasive species Red Lionfish (*Pterois volitans*) and the Devil Firefish (*Pterois miles*) which both have the common name the lionfish. They

are both in the Scorpionfish family and can range in size usually up to 47 cm. There is also a management section on how actions are taking place to help control their populations.

Wurzbacher, J. 2011. The Lionfish Invasion. Sailors of the Sea. Available: <http://sailorsforthesea.org/resources/ocean-watch-essays/lionfish-invasion> Accessed: 4/14/14.

Lionfish are a problem and not many solutions have been came up with in how to deal with the over population of this invasive species. Due to the extent of the lionfish invasion, control is now the only option as attempts to eradicate existing lionfish populations would be impractical and probably unsuccessful. This website addresses the problem of Lionfish and why it will have a negative impact on the environment. It is speculated that the root of the problem was only 6 lionfish accidentally released from an aquarium during hurricane Andrew in 1992. This website is to help raise awareness about lionfish and there impacts on the environment.

Zimmerman, D. 11/11/2013. Lionfish: Is it Safe to Eat? Florida Sea Grant. Available: <https://www.flseagrant.org/news/2013/11/lionfish-safe-eat/> Accessed: 4/14/14.

Most people do not this of lionfish as an eatable fish, even though it is not traditional in many seafood markets the lionfish can be served as a seafood dish. Many people would probably not consider eating the lionfish but with its takeover of the Southern Atlantic Ocean people have been trying to find a beneficial use of this resource. This web page is directed toward the safety of preparing and consuming lionfish in U.S waters and the Caribbean.

Dustin Foote - revised

*Albins, M.A., and P.J. Lyons. 2012. Invasive red lionfish *Pterois volitans* blow directed jets of water at prey fish. Marine Ecology Progress Series 448: 1-5, 20.

This study examined how lionfish hunt by producing jets of water towards there prey. These jets of water confuse or distract the prey and allow the lionfish to swallow the prey whole. The researcher contributed the predatory success of lionfish to this behavior. All ages were observed hunting this way.

*Albins, M., and M. Hixon. 2013. Worst case scenario: potential long-term effects of invasive predatory lionfish (*Pterois volitans*) on Atlantic and Caribbean coral-reef communities. Environmental Biology of Fishes 96: 1151-1157.

This study sites the Pacific red lionfish as the most ecologically harmful marine fish introduction to date. Red lionfish are biologically suited for invading new habitat and have strong negative effects on the local ecology including “defensive venomous spines, cryptic form, color and behavior, habitat generality, high competitive ability, low parasite load, efficient predation, rapid growth, and high reproductive rates.” This study looks at

both current ways to manage lionfish growth, and future methods of minimizing their disturbance. Enhancing native biotic resistance is discussed in relation to marine reserves and cultivating natural enemies.

*Alexander, J., B. Claydon, M.C. Calosso, and S.B. Traiger. 2012. Progression of Invasive Lionfish in Seagrass, Mangrove, and Reef Habitats. *Progression of Marine in Progress Series* 448: 119-129.

This study tracks the invasion of the Indo-Pacific lionfish down the North and South American eastern coastlines. The study showed a 7-month lag between first lionfish sighting and significant sighting numbers. Lionfish were shown to colonize shallow reef habitats prior to moving to deeper reef systems where their densities were greatest. Reefs with high vertical structures were preferred. The lionfish showed no preference between sea grass, mangrove, sheltered reef, and exposed reef habitats, however densities were lowest in shallow habitats with smaller fish.

*Barbour, A.B., M.S. Allen, T.K. Frazer, and K.D. Sherman. 2011. Evaluating the Potential Efficacy of Invasive Lionfish (*Pterois volitans*) Removals. *Public Library of Science One* 6(5): 1371.

This study used age structured population models to evaluate the efficacy of lionfish removal programs. Computer models predicted that lionfish would recover 90% of unfished biomass within 6 years. Researchers conclude that eradication of lionfish is highly unlikely by removal however substantial reduction of adults on a long-term commitment can cause reductions. Researchers suggest targeting specific areas where long term annual exploitation can be “intense” could be an effective measure of reducing lionfish numbers.

*Cote, I.M., S.J. Green, J.A. Morris, J.L. Akins, and D. Steinke. 2013. Diet richness of invasive Indo-Pacific lionfish revealed by DNA barcoding. *Marine Ecology Progress Series* 472: 249-256.

These researchers examined lionfish stomach contents via DNA barcoding, which is a more reliable method for identifying partially or fully digested prey species. They DNA barcoded digested fish from the stomachs of 130 lionfish collected on Bahamian coral reefs and identified 37 fish prey species, 16 of which had previously not been recorded as part of the lionfish’s diet. This could represent as much as 54% of potential prey species on these reefs. Accurately measuring the species that are consumed by lionfish can help researchers determine their overall effect on reef ecosystems.

*Darling, E.S., S.J. Green, J.K. O’Leary, and I.M. Cote. 2011. Indo-Pacific lionfish are larger and more abundant on invaded reefs: a comparison of Kenyan and Bahamian lionfish populations. *Biological Invasions* 13(9): 2045-2051.

This study compares native populations of indo-pacific lionfish with invasive populations in the Atlantic, Caribbean, and the Gulf of Mexico. Using standard field surveys these researchers compared lionfish densities, body size, biomass, and behavior between native and invaded coral reefs. The study showed that invaded reefs had high density and body size. However native lionfish had 5 other lionfish species to compete with whereas invasive populations did not. Researchers believed that this difference drove the biomass up in the invasive populations.

*Green, S.J., J.L. Akins, and I.M. Cote. 2011. Indo-Pacific lionfish on Bahamian coral reefs. *Marine Ecology Progress Series* 433: 159-167.

This study investigates the foraging behavior of indo-pacific lionfish on Bahamian coral reefs. Researchers tried to better understand lionfish interactions with novel environments by looking at their feeding patterns. They showed that lionfish hunted primarily at dawn and dusk but were opportunistic throughout the day. Daily consumptions was estimated three times higher than previous estimates obtained from captive lionfish and lionfish in their native ranges.

*Leon, R., K. Vane, P. Bertuol, V.C. Chamberland, F. Simal, E. Imms, and M.J.A. Vermeij. 2013. Effectiveness of lionfish removal efforts in the southern Caribbean. *Endangered Species Research* 22:175-182.

This study looked at the effectiveness of spear fishing to remove invasive lionfish in the Caribbean. Two areas were studied where removal efforts had been going on since initial lionfish sightings. Researchers showed that significant biomass reduction was possible but recruitment from un-fished locations still kept lionfish populations high. Problems with sharks interfering with divers was mentioned in this study.

*Leung, M., D. Padilla, N. Shemer, J. Vinagera, and B. Song. 2011. A Symmetric Intraguild Predation Model for the Invasive Lionfish and Native Grouper. *Arizona State University Press* 2011: 1-31.

This is an in-depth study on the relationship between groupers and lionfish. Both are considered top-level predators in reef ecosystems. This study shows lionfish and grouper interactions at various ages and how groupers act as a control agent for lionfish and vice versa. The researchers concluded that groupers did not limit lionfish growth. This is not a peer-reviewed resource.

*Morris, J.A., A. Thomas, A. Rhyne, N. Breen, L. Akins, and B. Nash. 2011. Nutritional properties of the invasive lionfish: A delicious and nutritious approach for controlling the invasion. *Aquaculture, Aquarium, Conservation & Legislation - International Journal of the Bioflux Society* 4(1): 21-26.

The lionfish species *Pterois volitans* and *Pterois miles* are native to the indo-pacific and are recent invaders to the western Atlantic Ocean. One strategy for control their populations is promoting them as a viable food source for local commercial fishermen. This study shows that lionfish meat contains higher levels of n-3 fatty acids than many highly consumed native marine fish species. Lionfish also have high fillet yield, over 30% of their wet weight. Research showed that lionfish meat was accepted by many consumers.

*Morris, J.A., K.W. Shertzer, and J.A. Rice. 2011. A stage-based matrix population model of invasive lionfish with implications for control. *Biological Invasions* 13(1): 7-12.

This study used a stage-based population model to examine lionfish populations and control measures. Researchers concluded that larval mortality most effected population growth rate and adults and juveniles had high survival rates. Based on this matrix, 30% of adult lionfish had to be removed each month to reduced population growth. This model did show that sustained removal efforts could be effective if both juveniles and adults were targeted.

*Mumby, P.J., A. Harborne, and D.R. Brumbaugh. 2011. Grouper as a Natural Biocontrol of Invasive Lionfish. *Public Library of Science One* 10: 1371.

Lionfish have invaded the Caribbean region and have greatly affected reef ecosystems. This study examines control methods in their native ranges in an effort to understand how to manage them in their introduced areas. Large groupers have been recorded with lionfish in their stomach. This study looks at the effectiveness of groupers as a natural bio-control to lionfish. Researchers found that overfishing of groupers greatly decreased their ability to control lionfish populations. Marine reserves had the highest grouper biomass and lowest lionfish densities. This could be because marine reserves managers used other methods of reduction.

*Munoz, R.C., C.A. Currin, and P.E. Whitfield. 2011. Diet of invasive lionfish on hard bottom reefs of the Southeast USA: insights from stomach contents and stable isotopes. *Marine Ecology Progress Series* 432: 181-193.

In order to effectively manage lionfish invaders, it is important to understand their biology and ecology, particularly their predatory interaction with local reef systems. These researchers collected lionfish from 18 in Onslow Bay, North Carolina in 2004 and 2006. Stomach content showed a generalist carnivorous diet of fish. *Serranidae* and *Scaridae* were prevalent in the diet in 2004, and *Haemulidae* and *Carangidae* were common in 2006. Researchers concluded that given the broad range of their diet that there would be significant impacts to the local fish communities.

*Pimiento, C., J.C. Nifong, M.E. Hunter, E. Monaco, and B.R. Silliman. 2013. Habitat use patterns of the invasive red lionfish *Pterois volitans*: a comparison between mangrove and reef systems in San Salvador, Bahamas. *Marine Ecology* 10:1111.

A previous study showed cited earlier that lionfish in deep reefs are larger in size than shallow ecosystems. This study ontogenetically investigated whether lionfish were using these shallow systems such as mangrove swamps as nurseries. These researches concluded that there was no difference in body size or overlap in the use of habitats or food resources. They suggest that lionfish do not single out areas for reproduction; instead they go through all life stages in one area. This was consistent with previous studies that showed lionfish as opportunistic foragers with little movement across habitats.

*Pusack, T., M. Albins, K. Ingeman, W. Raymond, and M. Hixon. 2014. Interactions Between Invasive Lionfish and Native Nassau Grouper. *Environmental Biology of Fishes* 2014: 1-9.

The red lionfish is an established invasive species spreading down the east coast of North and South America. The Nassau grouper is another predatory species that uses similar resources. This study shows that competition between these species centers around habitat and shelter rather than predation or similar food sources. Nassau groupers prefer isolated shelters, and were often disrupted by lionfish invaders. No predation between the two species was noted in the study. These researchers concluded that smaller groupers were more affected by lionfish.

Olivia Green

*Albins, M. M. A. Hixon. 2011. Worst case scenario: potential long-term effects of invasive predatory lionfish (*Pterois volitans*) on Atlantic and Caribbean coral-reef communities. <http://course.tjau.edu.cn/aqua/uploadfile/2012121715256837.pdf>. Accessed 4/10/14.

This paper describes the “worst case” scenario that could happen if the lionfish population is not controlled. The direct and indirect effects of preexisting stressors such as over fishing will cause substantial deleterious changes in coral-reef communities. It also talks about management actions that include developing targeted lionfish fisheries and local removal. Also by enhancing native biotic resistance, particularly in marine reserves which could conserve and foster potential lion fish enemies.

CAR-SPAW-RAC. 2013. The Problem of Lionfish in the Caribbean. [Car-spaw-rac.org](http://www.car-spaw-rac.org). http://www.car-spaw-rac.org/IMG/article_PDF/article_a451.pdf. Accessed 4/10/14.

It has been found that control is an effective way to decrease the negative effects of lionfish, however the control schemes must be aligned and focused on common objectives throughout the Caribbean (regional strategy). Available resources and size of management area determine control level. Nevertheless, the colonization pattern of the species, i.e. its capacity to move between sites, makes coordination and collaboration at the national and regional levels a key factor for success.

Cousteau, P., M. Knight. 2012. Taming the lionfish; Florida fights back against invasive species. CNN.com. <http://www.cnn.com/2012/04/24/us/lionfish/>. Accessed 4/10/14.

In an effort to minimize their impact, REEF run a monthly contest, open to both businesses and individuals, awarding prizes to those who catch the most lionfish. It also runs workshops on how to handle the venomous spikes. They're also putting it on the menu to show people that they are not dangerous to eat and can be very tasty.

*Gulli, J. 2012. A Practical Solution to Lionfish Management: CORE Foundation's Caribbean Lionfish Response Program. The CORE Foundation. http://procs.gcfi.org/pdf/GCFI_63-68.pdf. Accessed 4.10.14.

CORE has successfully developed and implemented an efficient, yet simple, lionfish management program using bilateral marine management strategy, the Caribbean Lionfish Response Program. It will place divers in the water to locate and remove lionfish. While also educating local and visiting user groups, youth, and the general public of the threat that the lionfish pose to the coral reef, fisheries, and tourism. Working together at local agencies, environmental organizations, dive shops, divers, and local fisherman and tourists allows CORE to utilize all resources at once.

*Moonsammy, S. D. Buddo, G. Seepersad. 2012. Assessment of the Impacts of the Lion Fish (*Pterois volitans*) in Jamaica. http://procs.gcfi.org/pdf/GCFI_64-13.pdf. Accessed 4/10/14.

The research establishes a baseline cost of the lionfish invasion which can be used to derive more detailed economic analysis. The results of this research can be used by government officials to quantify in economic terms the presence of Lionfish and develop the necessary policies to effectively manage the situation.

*Morris, J.A., J.L. Akins, D.A. Buddo., S.J. Green. R.G. Lazano. 2012. Invasive Lionfish, a Guide to Control and Management. NOAA. http://lionfish.gcfi.org/manual/InvasiveLionfishGuide_GCFI_SpecialPublicationSeries_Number_1_2012.pdf. Accessed 4/10/14.

An information and guide manual to the management and control of the lionfish invasion. Includes several management plans and studies done on the biology of the lionfish.

Netburn, D. 2014. Attack of the lionfish: Can they be stopped? Loss Angeles Times. <http://articles.latimes.com/2014/jan/25/science/la-sci-sn-war-on-lionfish-20140123>. Accessed 4/10/14.

A new study published in the journal of Ecological Applications finds that you don't have to remove all the lionfish from a reef in order for native fish populations to return, just most of them. Using computer models, as well as data collected from 24 coral reefs near Eleuthera Island in the Bahamas, the research team found that if 75% to 95% of the lionfish on a single reef were removed, the native fish would increase 50% to 70% within 18 months.

Noaa Ocean Service education. No Date. The Lion Fish Invasion! Oceanservice.noaa.gov. http://oceanservice.noaa.gov/education/stories/lionfish/lion05_stop.html. Accessed 4/8/14

With regards to the lionfish problem North Carolina is experiencing, scientists currently have five main suggestions: Track the lionfish population. Is the population actually growing? Or have more reports by the public made it appear that way. Conduct more research. So far, there is not much knowledge regarding future abundance or their effect on the eco system. Educate the public. People need to know that releasing their pets into the wild is not okay. Notify physicians and other health care providers about venomous fish in the U.S. water. Also to make regulations to the introduction of non-native marine species.

Olson, R. No Date. The Lionfish PSA. [deathtolionfish.org](http://www.deathtolionfish.org). <http://www.deathtolionfish.org/facts.html>. Accessed 4/9/14.

The "Invasion" started most likely as a result of escapes or releases from aquariums or hobbyists. After Hurricane Andrew, a lionfish was seen swimming about near a damaged house. Some countries are considering exporting live juveniles as a way of controlling their lionfish problem, but this approach can only further contribute to the problem elsewhere.

Spencer, E. 2013. Top Five Myths About Lionfish. Explorers Journal. <http://newswatch.nationalgeographic.com/2013/07/19/top-5-myths-about-lionfish/>. Accessed 4/10/14.

The only times it has been documented that sharks, eels, and grouper have eaten lionfish, is when it was given to them by a human. It may not be good to train these animals that every time they see a human they should get a free meal. Also, a study was released that examined that lionfish/predator abundance throughout the Caribbean over the course of three years determined that there was no correlation between native predator densities and lionfish densities. It appears as if humans are the only true predators of lionfish.

Talton, T. 2013. Lionfish Tournament: if You Can't Beat 'Em, Eat 'Em. North Carolina Coastal Federation. <http://www.nccoast.org/article.aspx?k=6427ca4e-9edb-4454-95b4-ae28f62d8fa3>. Accessed 4/10/14.

Since REEF sponsored its first derby in Green Turtle Cay, Abaco, Bahamas in 2009, more than 10,000 lionfish have been removed from the Caribbean and Atlantic. Upwards of 3,000 lionfish have been removed from one derby. That number is significantly higher than the 250 or so lionfish taken during the tournament in Morehead City. The derby offers awards for most fish caught, while also educating on how to cook and handle the fish. Very similar to a festival.

The Nature Conservancy. No Date. Managing Risks from Invasive Species. Coral Reefs; a Module of the Reef Resilience Toolkit. http://www.reefresilience.org/Toolkit_Coral/Mgmt_Strategies/MgmtStrategies_Intervention_Invasive.html. Accessed 4/10/14.

In the Caribbean, where lionfish have also invaded, some management plans they use, are by issuing special lionfish removal permits in marine protected areas and sanctuaries. Also, they encourage local fishers to catch and encourage a market for the lionfish through education campaigns, including brochures explaining how to safely handle and prepare lionfish.

U.S. Department of interior. 2012. Lionfish Response Plan; a Systematic Approach to Managing Impacts from the Lionfish, and Invasive Species, in Units of the National Park System. National Resource Report. Natural Resource Stewardship of the Interior. http://www.nature.nps.gov/water/marineinvasives/assets/documents/Lionfish_Response_Plan_%20final_small.pdf. Accessed 4/10/14.

The plan describes Service-wide approaches for lionfish management and then guide park managers and staff in developing site based plans specific to individual park units and conditions. Specific actions to prevent or mitigate resource impacts, to protect health and safety and to communicate the story of the lionfish invasion to partners, cooperators and the public are described.

Waite, R. 2011. Lionfish Invasion Threatens Coral Reefs in the Atlantic and Caribbean. World Recourses Institute. <http://www.wri.org/blog/lionfish-invasion-threatens-coral-reefs-atlantic-and-caribbean>, Accessed 4/10/14.

Governments across the Caribbean region are developing lionfish management plans, seeing that a huge revenue comes in from the coral reefs, which are being threatened by the lionfish invasion. Some governments (like U.S. and Jamaica) are initiating campaigns to promote human consumption of lionfish. Other management effort are focused on training divers to capture lionfish, and hosting derby style events where they remove large amounts of fish at once.

Xu, Daniel. 2013. Fishing News: Lionfish Invasion Continues, Scientists Seek Submersible Solutions. Outdoor Hub. <http://www.outdoorhub.com/news/lionfish-invasion-continues-scientists-seek-submersible-solutions/>. Accessed 4/14/14.

During a dive in a five person submersible, it was noticed that a school of fish were using the tires as a hiding place, and lionfish went for them, unafraid of the craft. Observations of this led to a project in the works by submarine company OceanGate's CEO Stockton Rush to build a suction device that will pull lionfish into a holding tank inside the submersible. The idea, while only in its earliest stages, is being considered by NOAA.

Andrew Jones

Atlantis Charters. May 5, 2013. A Detailed History of Lionfish in North Carolina. Atlantis Charters. <http://www.atlantischarters.net/lionfish.htm>. (Accessed 4/13/2014).

This webpage contains a detailed timeline of the history of lionfish in North Carolina Waters. It starts with the first sighting by divers on August 10, 2000 and actually has pictures from this dive of the first lionfish. Then a year later there is a list of 19 locations where lionfish had been observed. In 2008 the lionfish are said to be everywhere, being compared to cockroaches on a rock or ledge.

Discovery Diving Co. No Date. 2nd Annual If you cant beat 'em, eat 'em Lionfish/Lobster Tournament. Discovery Diving Company. http://discoverydiving.com/index.php?option=com_content&view=article&id=408&Itemid=173. (Accessed 4/12/2014)

This is an interesting article/advertisement for a spearfishing tournament for lionfish. The advertisement discussed why these fish need to go explain how they have no natural predators, eat half their body weight a day, lay 40,000 eggs every four days, and how tradition fishing methods have been ineffective.

Discovery Diving Co. July 21, 2012. Hunting Lionfish in North Carolina with Discovery Diving. Youtube. <http://www.youtube.com/watch?v=ElijMyGdCbo>. (Accessed 4/14/2010).

I decided to include this video in my annotated bibliography because it is a cool video showing how lionfish can be caught. It also shows how extreme the problem has become off North Carolina as the man spearfishing catches over a dozen Lionfish in just a few minutes.

Gupta, Anika. May 8, 2009. Invasion of the Lionfish. Smithsonian Magazine. <http://www.smithsonianmag.com/science-nature/invasion-of-the-lionfish-131647135/?no-ist>. (Accessed 4/12/2014).

This article starts out by discussing how the lionfish invasion may have started. It says that genetic tests suggest that as little as three lionfish were the initial population. Also

she states that in 1992, hurricane Andrew capsized many transport boats that could have led to introduction of the invasive lionfish. She then goes on to discuss how the lionfish have become a pervasive species in just a few years to the point where the situation in the western Atlantic may be irreversible.

Kimball, M. E., Miller, J. M., Whitfield, P. E., & Hare, J. A. (2004). Thermal tolerance and potential distribution of invasive lionfish (*Pterois volitans/miles* complex) on the east coast of the United States. *Marine Ecology Progress Series*, 283, 269-278.

The researchers in this paper aimed to determine the temperature threshold for lionfish in the Southeast United States. They wanted to determine this because it could help map the possible range of the lionfish invasion. Using aquarium and lab based experiments the researchers were able to determine the lionfish begin to stop eating when the water temperature reaches about 16 degrees Celsius and lionfish begin to die off when the water drops to about 10 degrees Celsius. They also found that the rate of decrease has little effect of when these anomalies occur. With this information these researchers determined that lionfish could survive the winter in the waters from North Carolina South but any further north than that, these fish could see high mortality rates during a particularly cold winter.

Maurer, Kevin. September, 2010. Diving in Deep. *Our State: North Carolina*.
<https://www.ourstate.com/lionfish/>. (Accessed 4/10/2014).

This article starts out with a personal account of Debby Boyce. Debby is an avid diver who frequents the waters off North Carolina. She describes one day where she went out to the most tropical reef she knows within range of the coast. She was looking forward to sitting on the reef and watching the vast schools of colorful fish swim around her. But when she got to the bottom all the tropical fish were gone and all she could see were Lionfish, Hundreds of them. The article then goes on to explain how lionfish got to this point and ways we can all work to reduce the invasion.

*Morris, J.A., Jr. (Ed.). 2012. *Invasive Lionfish: A Guide to Control and Management*. Gulf and Caribbean Fisheries Institute Special Publication Series Number 1, Marathon, Florida, USA. 113 pp.

This is a large 127 page book put together by Dr. James Morris and his colleagues detailing the lionfish problem. If you want to learn the most about lionfish this book is where to look. Over seven chapters everything you need to know about the lionfish is explained in great detail. From the past, present, and future of the lionfish, current finding and remaining questions, education about the lionfish and outreach, control strategies, monitoring the species, legal and regulatory considerations, and resources, everything you need you can find in this book.

NOAA. No Date. The Lionfish Invasion!. NOAA ocean service education. http://oceanservice.noaa.gov/education/stories/lionfish/lion02_invade.html. (Accessed 4/12/2014).

This is another article generally explain what the lionfish invasion is and how it happened. In August, 2002 divers off North Carolina saw lionfish for the first documented time. This was a surprise because Lionfish are known to be native to the warm Indo-Pacific waters. These divers collected a lionfish specimen as proof that they were indeed invading NC. One year later scientists had confirmed over 19 locations off North Carolina where lionfish had been sighted. This article stated that the invasion likely began when people with aquariums who kept lionfish as pets no longer wanted these fish and purposely released them into the Atlantic.

Pasko, Susan. 2005. Lionfish. Aquatic Nuisance Species Task Force. <http://www.anstaskforce.gov/spoc/lionfish.php>. (Accessed 2/13/2014).

This is an informative profile about the lionfish. Within, you can find the generally biology of the lionfish species that is invading the Atlantic coast as well as the history of the species as it journeyed from the Western Pacific to Western Atlantic. The profile next talks about the risks and impacts posed by the invading lionfish. Management strategies for reducing the lionfish population include physical removal from reefs. The webpage makes it clear to never release these fish as well as any aquarium fish into the wild.

*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(3), 473-479.

This paper researches the extent and timeline of the lionfish invasion in the Western Atlantic. The lionfish is the first non-native fish to invade the Western Atlantic. The researchers in this paper looked at records from the United States Geological Survey's Nonindigenous Aquatic Species Database to determine their extent. It is currently known that the lionfish have established large breeding populations from Cape Hatteras, North Carolina to the Florida Keys and across most of the Caribbean Islands. There have been reports of lionfish in the Gulf of Mexico and Central America but these populations are believed to not be established yet.

The Raleigh Telegram. June 24, 2013. Venomous Lionfish Invades NC Waters, But Tastes Surprisingly Good. Raleigh Telegram. <http://raleightelegram.com/201306245528>. (Accessed 4/10/2014).

This article begins by talking about how many people are becoming familiar with Lionfish as they have been in NC waters for some time now. It states that several large hurricanes in the past decade may have pushed the fish further north. It is also said that lionfish eat more than 50 species of fish and some of which are ecologically and economically important to the state. It says that traditional methods of fishing have not

been successful when dealing with the lionfish but fisherman are working to develop traps to catch the fish. The article also states how the lionfish are surprisingly delicious to eat and has a recipe on how they can be prepared.

Wheatley, Anne. Early Summer 2008. Naturalist's Notebook: Lionfish: Where Are They Now?. Sea Grant North Carolina. <http://www.ncseagrant.org/home/coastwatch/coastwatch-articles?task=showArticle&id=606>. (Accessed 4/12/2014).

Because of its history of pirates and shipwrecks, North Carolina's water has been a popular destination for scuba divers. Now, a new spectacle is luring divers and scientists: The Lionfish. Lionfish were first observed in North Carolina's waters in 2000, since then the population has increased dramatically. Genetic research has uncovered two different lionfish species invading North Carolina waters. Since lionfish generally live from 40-100 meters conducting research is very difficult. This article goes on to discuss the current and potential impacts of the Lionfish.

Whitfield, P. E., Gardner, T., Vives, S. P., Gilligan, M. R., Courtenay Jr, W. R., Ray, G. C., & Hare, J. A. (2002). Biological invasion of the Indo-Pacific lionfish *Pterois volitans* along the Atlantic coast of North America. *Marine Ecology Progress Series*, 235, 289-297.

The Lionfish (*Pterosis Volitans*) has been observed along the western Atlantic from North Carolina down to Georgia and Florida. Some have even been collected off the coast of New York. These fish are a rapidly moving and reproducing invasive species that are taking over the Atlantic. These fish are native to the tropical waters of the Indo-Pacific islands. It is believed that they were introduced by humans to the Atlantic, most likely after aquarium pets were released. It is also noted that Atlantic continental shelf reefs are becoming increasingly tropical of the last decade, which may aid in the dispersion of the Lionfish. Either way these fish are seen as detrimental to the economy and ecosystem and it is unanimous that they need to go. This paper highlights how they were introduced, the ecological impacts of the lionfish, and what we can do in the future to help eradicate this invasive species.

*Whitfield, P. E., Hare, J. A., David, A. W., Harter, S. L., Munoz, R. C., & Addison, C. M. (2007). Abundance estimates of the Indo-Pacific lionfish *Pterois volitans/miles* complex in the Western North Atlantic. *Biological Invasions*, 9(1), 53-64.

This paper looks into exactly how many Lionfish are now in the Western Atlantic and how far they have spread. Native grouper populations are also observed to see if there is any correlation between the two species. Two different studies were used to estimate populations. In the first study, scuba divers used visual transect surveys at 17 locations of the North Carolina coasts at depths from 30m-50m. In the second study a remote operated vehicle did transect surveys at five locations from North Carolina to Florida. The largest numbers of lionfish were observed in shallow North Carolina waters. It is believed that the invasion is irreversible at the point it has currently gotten to.

Wilcox, Christie. July 1, 2013. The Worst Marine Invasion Ever. Slate.com.

http://www.slate.com/articles/health_and_science/science/2013/07/lionfish_invasion_the_invasive_fish_are_eating_so_many_native_species_that.html. (Accessed 4/12/2014).

This article is a personal account of a girl's interaction with lionfish and Dr. James Morris. She discussed how when she dissected her first North Carolina lionfish she had no idea what the white waxy substance in their gut was. But Dr. Morris points it out to be fat, and a lot of it. She then explained how North Carolina lionfish are becoming obese, as if the problem weren't already bad enough.

Haley Quarles - revised

Anonymous. No Date. Red Lionfish (*Pterois volitnas*). Georgia Aquarium.

<http://animalguide.georgiaaquarium.org/home/galleries/georgia-explorer/gallery-animals/red-lionfish> . Accessed: 4/8/2014.

The Georgia Aquarium's website provides information on the Red Lionfish which appears in the aquarium. Question that are most frequently asked by visitors to the aquarium's workers are answered on the website. The answers include the range/ habitat of the Red Lionfish, their physical characteristics, their diet/ feeding, their reproduction/ growth, and other additional information on the species.

Anonymous. No Date. *Pterois volitnas*. Fishbase.org.

<http://www.fishbase.ca/Summary/speciesSummary.php?ID=5195&AT=Red+Lionfish> . Accessed: 4/8/2014.

Fishbase.org provides the classification/name of the Red Lionfish. The website also provides the environment/climate/range in which the Lionfish is found. A short description, the distribution, and the biology of the Red Lionfish are provided on the website. The length at first maturity/size/and range are also listed on the website.

Anonymous. No Date. The IndoPacific lionfish invasion of the U.S. south Atlantic sea coast and Caribbean Sea. U.S. Department of Commerce: National Oceanic and Atmospheric Administration, Coral Reef Information System. <http://www.coris.noaa.gov/exchanges/lionfish/> . Accessed: 4/8/2014.

The website is provided by NOAA's coral reef information system. It includes a description of the invasion of Lionfish that has occurred in the Atlantic Ocean. There is an introduction and background on the issue and a synopsis of participant discussions, which includes the impact on coral reef ecosystems. Included on the website is a map of all of the lionfish sightings, as well as the dispersal of the species. The website also includes a section on education, research, and communication. An explanation on population control, threats to humans, and future possible range of extension of the lionfish are included on the website.

*Betancur, R., A. Hines, A. Acero, G. Orti, A. Wilbur, and D. Freshwater. 2011. Reconstructing the lionfish invasion: insights into Greater Caribbean biogeography. *Journal of Biogeography* 38: 1281-1293.

This journal article is about the lionfish invasion that is occurring off of Florida's coast and the Atlantic Ocean. Mitochondrial DNA was obtained from lionfish individuals and analyzed. It was concluded that the lionfish dispersal occurred from a single source of introduction in Florida and not from multiple independent introductions across the ocean.

*Cote, I., S. Green, and M. Hixon. 2013. Predatory fish invaders: Insights from Indo-Pacific lionfish western Atlantic and Caribbean. *Biological Conservation* 164: 50-61.

This article discusses the invasion of western Atlantic marine habitats by two predatory Indo-Pacific Lionfish. Which has recently unfolded at an unpredictable rate, there are ecological consequences that are anticipated to be relatively large. Recently accumulated knowledge about lionfish ecology and behavior are examined and used to help understand the patterns and processes that lead to marine predator invasions.

*Frazer T., C. Jacoby, M. Edwards, S. Barry, and C. Manfrino. 2012. Coping with the Lionfish Invasion: Can Targeted Removals Yield Beneficial Effects? *Reviews in Fisheries Science* 20: 185-191.

The results from this case study suggest that targeted removals present a viable option when it comes to shifting the direct impacts of invasive lionfish away from highly vulnerable components of the ecosystem that this invasion is effecting. Invasive species, like the Red Lionfish, generate significant environmental and economic costs. Indo-Pacific lionfish are further threatening already stressed coral reefs in the western Atlantic Ocean and Caribbean Sea.

Gupta, A. May 8, 2009. Invasion of Lionfish: Voracious, venomous lionfish are the first exotic species to invade coral reefs. Now divers, fishermen-and cooks-are fighting back. *Smithsonian.com*. <http://www.smithsonianmag.com/science-nature/invasion-of-the-lionfish-131647135/?page=2> . Accessed: 3/17/2014.

This article written by Anika Gupta for *Smithsonian.com* states that it took as few as three lionfish to start the invasion. Genetic test suggest that there were not many lionfish involved in the starting of the invasion. These few lionfish laid hundreds of eggs; the larvae drifted with the current, and grew into adults. Which are capable of reproducing every fifty-five days and through all seasons. The fish that was once unknown to the Americas only thirty years ago now lives among their reefs and wrecks. In 2000 a recreation diver spotted two tropical lionfish off of the coast of North Carolina, 140 feet below the surface. Once the National Oceanographic and Atmospheric Administration was alerted, lionfish sightings in the Atlantic began being traced. After only two years, the fish was then seen in Georgia, Florida, Bermuda and the Bahamas. The article also includes a description on the first exotic species to invade coral reef's natural habitat and an explanation as to why they are growing uncontrollably in the Atlantic Ocean.

*Johnston, M. and S. Purkis. 2011. Spatial analysis of the invasion of lionfish in the western Atlantic and Caribbean. *Marine Pollution Bulletin* 62: 1218-1226.

This journal article contains the analyzed records based on spatial location, dates of arrival, and prevailing physical factors at the capture sights. A cellular automata model is used in order to examine the relationship between depth, salinity, temperature, and current. The current was found to be the most influential parameter for transport of lionfish to new areas.

Kroll, D. January 14, 2014. Christie Wilcox gets a taste of the Atlantic lionfish invasion. The Open Notebook. <http://www.theopennotebook.com/2014/01/14/christie-wilcox-lionfish-invasion/> . Accessed: March 17, 2014.

This article written by David Kroll is about why Christie Wilcox, a PhD student in Hawaii, came to Eastern North Carolina in order to study the lionfish. The article included questions asked by David Kroll pertaining to the lionfish invasion that is occurring off of North Carolina's coast. It provides detailed information on why the lionfish have become such a hot topic.

Maurer, K. No Date. Diving in Deep. Our State North Carolina. <https://www.ourstate.com/lionfish/> . Accessed: 3/17/2014.

This article written by Kevin Maurer discusses in detail a local dive shop owner, Debby Boyce's first-hand experience with the invasive lionfish. Twenty-six miles southeast of the Beaufort Inlet, the Rock Pile thrives with colorful tropical fish. In the summer of 2005, Debby Boyce headed out for a dive in order to catch fish for her aquarium and was confronted with hundreds of lionfish. The Rock Pile, which is the most tropical place off of the coast of North Carolina had gone from beautiful colors to a swarm of lionfish. The article includes information about how Debby Boyce recruited spearfish divers to come collect hundreds of lionfish off of the reef in attempt to manage the invasive population.

Poe, K. April 5, 2013. NC fishing tournament targets lionfish, an unwanted guest in coastal waters. Charlotteobserver.com. http://www.charlotteobserver.com/2013/04/05/3963183/nc-fishing-tournament-targets.html#.Uydj_YWwWSo . Accessed: 3/17/2014.

The article written by Kelly Poe discussed the 2013, Morehead City first annual "If you can't beat 'em, eat 'em" spearfishing tournament. Which was aimed to educate the public about lionfish. The article stated that a \$500 prize would be awarded to the person who caught the most lionfish. Anyone who was scuba certified and had a recreational fishing license was encouraged to enter the contest, not matter what skill set they had. It is estimated that between 200 and 500 lionfish per 10,000 square meters are present off of the coast of North Carolina. The website also included a recipe for how to prepare lionfish.

Talton, T. June 24, 2013. Lionfish Tournament: If You Can't Beat 'Em, Eat 'Em. North Carolina Coastal Federation. <http://www.nccoast.org/article.aspx?k=6427ca4e-9edb-4454-95b4-ae28f62d8fa3> . Accessed: 3/17/2014.

This article by Trista Talton is about the ornamental fish, which are native to the South Pacific and Indian Oceans, lionfish. They have been popular household pets in aquariums. They were released into the Atlantic and the Caribbean and over the last 10 years have become a threat to native reef fish and their communities. The recent

estimated for lionfish off of the North Carolina coast range between 200 and 500 lionfish per 10,000 square meters. Early in June 2013 the first annual “If You Can’t Beat ‘Em, Eat ‘Em” spearfishing tournament occurred in Morehead City. They were described as tasting very much like a trigger fish. This article includes great information on the tournament as well as similar tournament that have occurred in nearby states in efforts to control the lionfish population.

Wheatly, A. 2008. Naturalist’s Notebook: Lionfish: Where Are They Now? Coastwatch Early Summer 2008: Sea Grant North Carolina.
<http://www.ncseagrant.org/home/coastwatch/coastwatch-articles?task=showArticle&id=606> .
Accessed: 3/17/2014.

This short article written by Anne Wheatly talks about how North Carolina’s coast is now a destination for both scuba divers and scientist to see lionfish. The tropical lionfish were first introduced in North Carolina’s Continental Shelf in 2000, since then the population has continued to grow. Lionfish have become common among many North Carolina wrecks. Many divers want to see the lionfish because they are beautiful and many enjoy taking pictures of them, from a distance of course, since they are venomous. The lionfish is described as being vibrantly colored with red-and-white strips and long protruding venomous spines. The lionfish are native to the Indo-Pacific region and it is believed they were introduced into the Atlantic Ocean from accidental or intentional aquarium releases. The article includes detailed information of the DNA discoveries that are being done as well as the ROV research.

Wilcox, C. July 1, 2013. The Worst Marine Invasion Ever. The Slate Group.
http://www.slate.com/articles/health_and_science/science/2013/07/lionfish_invasion_the_invasive_fish_are_eating_so_many_native_species_that.html . Accessed: 3/17/2014.

This article written by Christie Wilcox is about the worst marine invasion ever, which is the invasion of the lionfish. Christie came to North Carolina to study the lionfish invasion and met up with James Morris, who works at the National Ocean Service’s Center for Coastal Fisheries and Habitat Research in Beaufort, North Carolina. James has discovered “white chunky stuff” inside lionfish he has caught and dissected along the coast of North Carolina and has concluded that these lionfish are obese. And this is because lionfish eat everything in sight and have no natural predators in the Atlantic Ocean. It was once thought that lionfish arrived to these waters from coastal damage caused by Hurricane Andrew; however, it is now believed that individuals who bought them from aquariums began to release them in the wild and thrived and started a new population. This article contains great detail about the studies being conducted in order to make lionfish part of the fisheries in North Carolina in order to help control the invasive population.

*Williams, N. 2010. Major lionfish hunt launched. *Current Biology* 20: R1005-R1006.

This journal article discusses the Red Lionfish, which is native of the eastern Pacific, appears to be spreading rapidly around Florida. The Lionfish are making their way up the eastern seaboard and the Caribbean. This is growing alarm for many marine biologists.

They feed on native coral reef species, which worries conservationists. They have venomous spines which seem to scare off most potential predators.

Meganne Rose - revised

*Albins, M. A. and M. A. Hixon. 04/15/2011. Worst case scenario: potential long-term effects of invasive predatory lionfish (*Pterois volitans*) on Atlantic and Caribbean coral-reef communities. *Environmental Biology Fish* 96: 1151-1157.

Introduces the Red Lionfish as potentially one of the most harmful marine introductions to date. This entry goes on and details traits that make Lionfish, and the Red Lionfish in particular, successful invaders. Lionfish are highly competitive fish with broad habitat selectiveness, giving them almost every advantage over their prey and competitors.

*Arais-Gonzalez, J. E., C. Gonzalez-Gandara, J. L. Cabrera, and V. Christensen. 10/2011. Predicted impact of the invasive lionfish *Pterois volitans* on the food web of a Caribbean coral reef. *Invasive Species* 111 (7): 917-925.

Lionfish invasion is causing severe impact to coral reef food-webs. Using software to model the food webs with zero lionfish biomass, versus minimum lionfish biomass, and then versus steadily increasing lionfish biomass, food-webs were devastated by the increased predation by the lionfish. Several species were driven to extinction while the lionfish dominated.

*Cerino, D. S. 2010. Bioenergetics and Trophic Impacts of Invasive Indo-Pacific Lionfish. The Scholarship. *Biolog* 10342: 2724.

Bioenergetics models were made to mimic the lionfish in populations in the western North Atlantic Ocean that model the potential effects of the lionfish as a predator to these ecosystems. Estimates of growth rate and consumption by the lionfish show not only the lionfish driving down speciation in the reef habitats, but out competing other fish for living space.

*Claydon, J. A. B., M. C. Calosso, and S. B. Traiger. 2012. Progression of invasive lionfish in seagrass, mangrove and reef habitats. *Marine Ecology Progress Series* 448: 119-129.

Explains and examines the differences between lionfish succession rates in the three habitats; mangroves, reefs, and seagrasses. This also notes that there is an obvious staggering difference between the three areas, suggesting that while they can be viable in populations in all three environments, it may be easier to eradicate lionfish from one area versus another.

*Hackerott, S., A. Valdivia, S. J. Green, I. M. Cote, C. E. Cox, L. Akins, C. A. Layman, W.F. Precht, and J. F. Bruno. 07/11/2013. Native Predators Do Not Influence Invasion Success of Pacific Lionfish on Caribbean Reefs. *PLoS ONE* 8(7): e68259.

This paper backs the argument that even in the presence of natural predators, lionfish have a high success rate of invasion. Because of this, regardless of predator numbers, lionfish populations will continue to flourish.

*Kimball, M. E., J. M. Miller, P. E. Whitfield, and J. A. Hare. 11/30/2004. Thermal tolerance and potential distribution of invasive lionfish (*Pterois volitans/miles complex*) on the east coast of the United States. Marine Ecology Progress Series 283: 269-278.

This article poses temperature as the main abiotic factor that prevents the spread of the Red Lionfish invasion up the east coast of the United States. The invasion seems to have faltered at the North Carolina Coast, as waters above those geographical locations trend towards colder than the lionfish can successfully survive in.

Linendoll, K. 10/19/2013. Lionfish infestation in Atlantic Ocean a growing epidemic. Tech. Innovation. <http://www.cnn.com/2013/10/18/tech/innovation/lionfish-infestation-atlantic-linendoll/>. Accessed: 04/12/2014.

This article written by CNN details one stage of the beginning of the lionfish invasion, mentioning the aquarium spill and the release from home aquaria as both means of the introduction of lionfish to the Atlantic Ocean. From meager beginnings, the lionfish bred constantly, slowly but surely invading the coastal region.

*Meister, S. H., D. M. Wyanski, J. K. Loefer, S.W. Ross, A. M. Quattrini, and K. J. Sulak. 06/2005. Further Evidence for the Invasion and Establishment of *Pterois volitans* (Teleostei: Scorpaenidae) Along the Atlantic Coast of the United States. Southeastern Naturalist 4(2): 193-206.

Continued Documentation of the Invasion of the Red Lionfish. Goes into detail on the specific reef breeding populations. Details livable conditions for these fish, giving light to the vastness of their range. It goes on to show collection data from live bottom reefs in North and South Carolina, Florida, and off of manmade structures in Georgia. This goes into detail about the problems lionfish present to indigenous fish populations.

*Morris, J. A. Jr., and J. L. Akins. 10/27/2009. Feeding Ecology of Invasive lionfish (*Pterois volitans*) in the Bahamian archipelago. Environmental Biology Fish 86:389-398.

By doing gut content analysis, these scientists were able to find the eating habits of the Red Lionfish off the Bahamian Archipelago. They measured the findings in three specificities: quantity, percent number, and percent volume. These estimates were used to see preferred food and energy webs for Lionfish in order to further understand their new role in the places they have invaded, and to see if prey fish species could survive the invasion.

*Morris, J. A. Jr., A. Thomas, A. L. Rhyne, N. Breen, L. Akins, and B. Nash. 01/2011. Nutritional properties of the invasive lionfish: A delicious and nutritious approach for controlling the invasion. International Journal of the Bioflux Society 4 (1): 21-26.

This paper details the nutritional value of the Red Lionfish and suggests human consumption as a means of controlling the overwhelming lionfish populations. It also goes into how to properly remove lionfish spines in order to serve them safely and successfully.

*Morris, J. A. Jr., C. V. Sullivan, and J. J. Govoni. 2011. Oogenesis and spawn formation in the invasive lionfish *Pterois miles* and *Pterois volitans*. *Scientia Marina* 75: 1238.

This study done on *P. miles* and *P. volitans* collected off shore in North Carolina and in the Bahamas, details the egg formation and reproductive success of these two species of lionfish. The mode of reproduction used by these fish (Asynchronous, indeterminate batch spawning) has been a key factor in the success of this invasion.

Nature World News. 10/22/2013. Lionfish Wiping Away Native Marine Life of Atlantic Ocean. *Animals*. 4553. <http://www.natureworldnews.com/articles/4553/20131022/lionfish-wiping-native-marine-life-atlantic-ocean.htm>. Accessed: 04/10/2014.

This article by Nature World News, sheds more of a public opinion on the lionfish problem, rather than a scientific one. It accounts the species being wiped out by the lionfish takeover, and how diversity is decreasing under the constant predation by lionfish.

*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 (3): 473-479.

States that the Indo-Pacific Lionfishes (*P.volitans* and *P.miles*) are the first marine fish that are non-native fish who have been able to establish themselves in the Western North Atlantic. This addresses the timeline of the issue, how long the invasion took to take hold, and the extent of the lionfish domain now.

*Whitfield, P. E., T. Gardner, S. P. Vives, M. R. Gilligan, W. R. Jr. Courtenay, G. C. Ray, and J. A. Hare. 06/19/2002. Biological invasion of the Indo-Pacific lionfish *Pterois volitans* along the Atlantic coast of North America. *Marine Ecology Progress Series* 235: 289–297.

This paper marks the introduction of *Pterois volitans* into the Atlantic Ocean, by consistent catch rates of individuals, both juvenile and adult forms, along the Atlantic coast. This also states that natural predators of the Lionfish have been overfished in these waters, leading to the predicted outcome of invasion.

*Whitfield, P. E., J. A. Hare, A. W. David, S. L. Harter, R. C. Munoz, and C. M. Addison. 06/4/2006. Abundance estimates of the Indo-Pacific lionfish *Pterois volitans/miles* complex in the Western North Atlantic. *Biological Invasions* 9: 53-64.

Examines the invasion of the *Pterois volitans* off the coast of the Eastern United States based on range information and population numbers of Epiphelinae serranids, native

grouper, to get an estimate of lionfish spread less than a decade after the fish was first sighted off the coast of Florida.

Nina Sassano

*Albins, M., and M. Hixon. 2013. Worst case scenario: potential long-term effects of invasive predatory lionfish (*Pterois volitans*) on Atlantic and Caribbean coral-reef communities. *Environmental Biology of Fishes* 96 (10-11): 1151-1157.

This paper explores various different “worst-case” scenarios for different ecosystems in which the lionfish invades. It is believed by these authors that lionfish could potentially become apex predators in many disturbed ecosystems, where most reef-fish biomass is converted into lionfish biomass, leaving reefs void of natural fish populations except for those which are not prey of lionfish. These fish would include sharks and rays, although the pups of these animals could also become susceptible to lionfish predation. Between the fishing of major predatory fish and the predation of smaller fish by lionfish coral reef fish populations could be facing a complete shift in the future.

Barber, E. 2013. Lionfish Invasion: An unabated siege of the Atlantic. *Christian Science Monitor*. Available: <http://www.csmonitor.com/Science/2013/1021/Lionfish-invasion-An-unabated-siege-of-the-Atlantic>

This article was published in a response to research showing that the lionfish population has been booming off the coast of Florida. This article provides a general background of the information regarding the invasion of the lionfish to the Atlantic, and some of the things people are trying to do to remediate the invasion.

*Cerino, D., A. Overton, J. Rice, and J. Morris. 2013. Bioenergetics and trophic impacts of the invasive Indo-Pacific Lionfish. *Transactions of the American Fisheries Society* 142(6): 1522-1534.

Cerino *et al* developed a model showing the bioenergetics for the invasive Indo-Pacific lionfish. To do this, a series of laboratory experiments were conducted monitoring the effects of temperature, salinity and predator size on the energy density of the prey. After observing in lab experiments, the bioenergetics model was applied to predict population level impacts of an invasion of lionfish to non-native areas.

Discover Puerto Rico. 2013. A la Caza del Pez Leon! (The LionFish Hunt Festival). Discover Puerto Rico. Available: <http://discoverpuertoricousa.com/the-lionfish-hunt-festival/>

This webpage is for the LionFish Hunt Festival in La Parguera Beach, Puerto Rico. This festival will have exhibits discussing lionfish invasions in Puerto Rico, information about their ecology and biology and a professional chef who will demonstrate the variety of ways in which lionfish can be prepared and cooked along with free tastings. Along with

this, skilled hunters will be conducting a large ongoing experiment locating and removing lionfish from the island's coast.

Florida Dive Connection. 2014. 2014 Gulf Coast Lionfish Roundup: May 1-4. Gulf Coast Lionfish Roundup Series 2014. Available: <http://www.floridadiveconnection.com/event/2014-gulf-coast-lionfish-roundup/>

This page describes an event hosted by the Gulf Coast Lionfish Roundup Series in which public education will meet lionfish removal as contestants compete to eradicate the most amount of lionfish possible from the area. This is a several day festival with a grand prize incentive of \$4,000, as well as several smaller category trophies and prizes. The festival will be taking place at the Flora-Bama Yacht Club in Florida.

*Hackerott, S., A. Valdivia, S. Green, I. Cote, C. Cox, L. Akins, C. Layman, W. Precht, and J. Bruno. 2013. Native predators do not influence invasion success of Pacific Lionfish on Caribbean Reefs. PLoS ONE 8(7).

This study examines whether biotic resistance from species on Caribbean coral reefs has helped exacerbate invasion of non-native red lionfishes. To do this, relationships between lionfish and their potential predatory competitors were studied on over 70 reefs in the Caribbean. There was no correlation found between lionfish and their potential competitors, although habitat preference did play a role in lionfish settlement.

*Harold, A., D. Zurlo, C. Toline, S. Doty, and V. McDonough. 2013. Diet of red lionfish (*Scorpaenidae*) from Biscayne Bay, Florida, based on gut content analysis. Integrative and Comparative Biology 53: E293-E293.

Using a gut content analysis, the specific prey items of the invasive red lionfish in Biscayne Bay was determined. The results of this study show that the lionfish eats a total of 916 different prey items, including fish, crustaceans, and a gastropod. These results show that lionfish in the Biscayne Bay area feed mainly on the benthic fishes and crustaceans, and are also opportunistic predators.

*Loennstedt, O., and M. McCormick. 2013. Ultimate predators: Lionfish have evolved to circumvent prey risk assessment abilities. PLoS ONE 8(10).

This study proved that lionfish are practically undetectable by their main prey, the damselfish. In areas where the lionfish is invading, damselfish do not respond to their presence in an anti-predatory way in the same way they avoid their other natural predators, such as the predatory rock cod. Furthermore, the damselfish do react to the olfactory cue of the lionfish of a different genus *Dendochirus zebra*, although not the invasive *P. volitans*. This shows that this species of lionfish is able to avoid being detected as a predator in the systems it invades.

*Luiz, O., J. Osmar, S. Floeter, L. Rocha, and C. Ferreira. 2013. Perspectives for the lionfish invasion in the South Atlantic: are Brazilian reefs protected by the currents? *Marine Ecology Progress Series* 485: 1-7.

Lionfish populations have yet to spread to Brazil, although their presence has been predicted to spread throughout the entire western portion of the Atlantic. This study examined whether currents moving around Brazil are bypassing the area by analyzing fossil records of the species that have previously been found near the Brazilian Province. The results of the study show that although passage does come at a slower rate, the movement of the current will inevitably move lionfish into the area.

*Moore A. 2012. The Aquatic Invaders: Marine management figuring fishermen, fisheries and lionfish in the Bahamas. *Cultural Anthropology* 27(4): 667-688.

This article takes an anthropology-based view of the social impacts of lionfish on fisheries in the Bahamas. Provided is a brief history of the invasion of the fish into the Bahamas, as well as the history of the human reactions to the fish. This looks the development of fishermen and lionfish in the Bahamas as symbols of the time, and shows how fisheries can adapt to changing ecosystem inhabitants.

NOAA. 2013. Lionfish Biology Fact Sheet. National Oceanic and Atmospheric Administration. Available: <http://oceanservice.noaa.gov/education/stories/lionfish/factsheet.html>

This fact sheet provides information regarding various aspects of lionfish biology and conservation. Topics include: common names, scientific names, appearance, native and non-native ranges, habitat, ecological role, behavior, economic importance, conservation status and special precautions in regards to the lionfish.

*Nunez, M., S. Kuebbing, R. Dimarco, and D. Simberloff. 2012. Invasive Species: to eat or not to eat, that is the question. *Conservation Letters* 5(5): 334-341.

Although humans view eating invasive species as the go-to alternative to growing populations, this article shows some considerations that must be thought about before turning right to the over-consumption of invasive species. Once there is an established market for the species, there will be a continued market for this species, even once all invasives have been eradicated. Furthermore incorporating these species into the local market could lead to management and protection of this species, which could enable its future proliferation. Although there are some considerations to be made before mass marketing these fish as food, it provides a great opportunity for public outreach as the general population has the opportunity to learn about invasive species and the harms of introducing non-natives to a habitat.

*Pala, C. 2014. As lionfish invade, divers defend threatened ecosystems. *Science*. 343(6171): 591.

This article provides an overview of the history of the invasion of the lionfish into southwestern Atlantic waters. In 2013, using ecological modeling divers actually helped the native fish populations rebound on 24 coral reefs in the Bahamas by killing 75-95% of the sites, which allowed 50-70% of their prey populations to rebound. Pala believes that this kind of tactic could help decrease populations of invasive lionfish in other parts of the world.

*Stevens, J., and J. Olson. 2013. Invasive lionfish harbor a different external bacterial community than native Bahamian fishes. *Coral Reefs* 32(4): 1113-1121.

This study measured the bacterial communities within lionfish populations and compared these to the bacterial communities of native fish populations in the Bahamas, where the lionfish are an invasive species. The study found that the bacterial communities associated with lionfish were significantly different and more diverse than the bacterial communities of three native fish. This was the first study of its kind, and showed that lionfish are not the only invasive members of their community. Furthermore, this study shows the potential for the different bacterial communities to travel vertically through the water column on the lionfish egg sacs.

World Lionfish Hunters Association. 2014. Filleting, Cleaning and Preparing Lionfish to Eat. World Lionfish Hunters Association. Available: <http://lionfish.co/cleaning-and-preparing-lionfish-to-eat/>

This website provides “everything you ever wanted to know about filleting, cleaning, gutting, scaling and preparing lionfish but were afraid to risk”. It provides step-by-step instructions with visual aids to help the layman learn to fillet a lionfish safely. There are also several videos posted to help learn tricks to filleting the lionfish.

Amanda Sharp - revised

Anonymous. No Date. Red Lionfish (*Pterois volitnas*). Georgia Aquarium. <http://animalguide.georgiaaquarium.org/home/galleries/georgia-explorer/gallery-animals/red-lionfish> . Accessed: 4/8/2014.

The Georgia Aquarium’s website provides information on the Red Lionfish which appears in the aquarium. Question that are most frequently asked by visitors to the aquarium’s workers are answered on the website. The answers include the range/ habitat of the Red Lionfish, their physical characteristics, their diet/ feeding, their reproduction/ growth, and other additional information on the species.

Anonymous. No Date. *Pterois volitnas*. Fishbase.org. <http://www.fishbase.ca/Summary/speciesSummary.php?ID=5195&AT=Red+Lionfish> . Accessed: 4/8/2014.

Fishbase.org provides the classification/name of the Red Lionfish. The website also provides the environment/climate/range in which the Lionfish is found. A short description, the distribution, and the biology of the Red Lionfish are provided on the website. The length at first maturity/size/and range are also listed on the website.

Anonymous. No Date. The IndoPacific lionfish invasion of the U.S. south Atlantic sea coast and Caribbean Sea. U.S. Department of Commerce: National Oceanic and Atmospheric Administration, Coral Reef Information System. <http://www.coris.noaa.gov/exchanges/lionfish/>. Accessed: 4/8/2014.

The website is provided by NOAA's coral reef information system. It includes a description of the invasion of Lionfish that has occurred in the Atlantic Ocean. There is an introduction and background on the issue and a synopsis of participant discussions. Which, includes the impact on coral reef ecosystems. Included on the website is a map of all of the lionfish sightings, as well as the dispersal of the species. The website also includes a section on education, research, and communication. An explanation on population control, threats to humans, and future possible range of extension of the lionfish are included on the website.

*Betancur, R., A. Hines, A. Acero, G. Orti, A. Wilbur, and D. Freshwater. 2011. Reconstructing the lionfish invasion: insights into Greater Caribbean biogeography. *Journal of Biogeography* 38: 1281-1293.

This journal article is about the lionfish invasion that is occurring off of Florida's coast and the Atlantic Ocean. Mitochondrial DNA was obtained from lionfish individuals and analyzed. It was concluded that the lionfish dispersal occurred from a single source of introduction in Florida and not from multiple independent introductions across the ocean.

*Cote, I., S. Green, and M. Hixon. 2013. Predatory fish invaders: Insights from Indo-Pacific lionfish western Atlantic and Caribbean. *Biological Conservation* 164: 50-61.

This article discusses the invasion of western Atlantic marine habitats by two predatory Indo-Pacific Lionfish. Which has recently unfolded at an unpredictable rate, there are ecological consequences that are anticipated to be relatively large. Recently accumulated knowledge about lionfish ecology and behavior are examined and used to help understand the patterns and processes that lead to marine predator invasions.

*Frazer T., C. Jacoby, M. Edwards, S. Barry, and C. Manfrino. 2012. Coping with the Lionfish Invasion: Can Targeted Removals Yield Beneficial Effects? *Reviews in Fisheries Science* 20: 185-191.

The results from this case study suggest that targeted removals present a viable option when it comes to shifting the direct impacts of invasive lionfish away from highly vulnerable components of the ecosystem that this invasion is effecting. Invasive species, like the Red Lionfish, generate a significant environmental and economic costs. Indo-Pacific lionfish are further threatening already stressed coral reefs in the western Atlantic Ocean and Caribbean Sea.

Gupta, A. May 8, 2009. Invasion of Lionfish: Voracious, venomous lionfish are the first exotic species to invade coral reefs. Now divers, fishermen-and cooks-are fighting back. Smithsonian.com. <http://www.smithsonianmag.com/science-nature/invasion-of-the-lionfish-131647135/?page=2> . Accessed: 3/17/2014.

This article written by Anika Gupta for Smithsonian.com states that it took as few as three lionfish to start the invasion. Genetic test suggest that there were not many lionfish involved in the starting of the invasion. These few lionfish laid hundreds of eggs, the larvae drifted with the current, and grew into adults. Which are capable of reproducing every fifty-five days and through all seasons. The fish that was once unknown to the Americas only thirty years ago now lives among their reefs and wrecks. In 2000 a recreation diver spotted two tropical lionfish off of the coast of North Carolina, 140 feet below the surface. Once the National Oceanographic and Atmospheric Administration was alerted, lionfish sightings in the Atlantic began being traced. After only two years, the fish was then seen in Georgia, Florida, Bermuda and the Bahamas. The article also includes a description on the first exotic species to invade coral reef's natural habitat and an explanation as to why they are growing uncontrollably in the Atlantic Ocean.

*Johnston, M. and S. Purkis. 2011. Spatial analysis of the invasion of lionfish in the western Atlantic and Caribbean. *Marine Pollution Bulletin* 62: 1218-1226.

This journal article contains the analyzed records based on spatial location, dates of arrival, and prevailing physical factors at the capture sights. A cellular automata model is used in order to examine the relationship between depth, salinity, temperature, and current. The current was found to be the most influential parameter for transport of lionfish to new areas.

Kroll, D. January 14, 2014. Christie Wilcox gets a taste of the Atlantic lionfish invasion. The Open Notebook. <http://www.theopennotebook.com/2014/01/14/christie-wilcox-lionfish-invasion/> . Accessed: March 17, 2014.

This article written by David Kroll is about why Christie Wilcox, a PhD student in Hawaii, came to Eastern North Carolina in order to study the lionfish. The article included questions asked by David Kroll pertaining to the lionfish invasion that is occurring off of North Carolina's coast. It provides detailed information on why the lionfish have become such a hot topic.

Maurer, K. No Date. Diving in Deep. Our State North Carolina. <https://www.ourstate.com/lionfish/> . Accessed: 3/17/2014.

This article written by Kevin Maurer discusses in detail a local dive shop owner, Debby Boyce's first-hand experience with the invasive lionfish. Twenty-six miles southeast of the Beaufort Inlet, the Rock Pile thrives with colorful tropical fish. In the summer of 2005, Debby Boyce headed out for a dive in order to catch fish for her aquarium and was confronted with hundreds of lionfish. The Rock Pile, which is the most tropical place off of the coast of North Carolina had gone from beautiful colors to a swarm of lionfish. The

article includes information about how Debby Boyce recruited spearfish divers to come collect hundreds of lionfish off of the reef in attempt to manage the invasive population.

Poe, K. April 5, 2013. NC fishing tournament targets lionfish, an unwanted guest in coastal waters. Charlotteobserver.com. http://www.charlotteobserver.com/2013/04/05/3963183/nc-fishing-tournament-targets.html#.Uydj_YWwWSo . Accessed: 3/17/2014.

The article written by Kelly Poe discussed the 2013, Morehead City first annual “If you can’t beat ‘em, eat ‘em” spearfishing tournament. Which was aimed to educate the public about lionfish. The article stated that a \$500 prize would be awarded to the person who caught the most lionfish. Anyone who was scuba certified and had a recreational fishing license was encouraged to enter the contest, not matter what skill set they had. It is estimated that between 200 and 500 lionfish per 10,000 square meters are present off of the coast of North Carolina. The website also included a recipe for how to prepare lionfish.

Talton, T. June 24, 2013. Lionfish Tournament: If You Can’t Beat ‘Em, Eat ‘Em. North Carolina Coastal Federation. <http://www.nccoast.org/article.aspx?k=6427ca4e-9edb-4454-95b4-ae28f62d8fa3> . Accessed: 3/17/2014.

This article by Trista Talton is about the ornamental fish, which are native to the South Pacific and Indian Oceans, lionfish. They have been popular household pets in aquariums. They were released into the Atlantic and the Caribbean and over the last 10 years have become a threat to native reef fish and their communities. The recent estimated for lionfish off of the North Carolina coast range between 200 and 500 lionfish per 10,000 square meters. Early in June 2013 the first annual “If You Can’t Beat ‘Em, Eat ‘Em” spearfishing tournament occurred in Morehead City. They were described as tasting very much like a trigger fish. This article includes great information on the tournament as well as similar tournament that have occurred in nearby states in efforts to control the lionfish population.

Wheatly, A. 2008. Naturalist’s Notebook: Lionfish: Where Are They Now? Coastwatch Early Summer 2008: Sea Grant North Carolina. <http://www.nceagrants.org/home/coastwatch/coastwatch-articles?task=showArticle&id=606> . Accessed: 3/17/2014.

This short article written by Anne Wheatly talks about how North Carolina’s coast is now a destination for both scuba divers and scientist to see lionfish. The tropical lionfish were first introduced in North Carolina’s Continental Shelf in 2000, since then the population has continued to grow. Lionfish have become common among many North Carolina wrecks. Many divers want to see the lionfish because they are beautiful and many enjoy taking pictures of them, from a distance of course, since they are venomous. The lionfish is described as being vibrantly colored with red-and-white strips and long protruding venomous spines. The lionfish are native to the Indo-Pacific region and it is believed they were introduced into the Atlantic Ocean from accidental or intentional aquarium releases. The article includes detailed information of the DNA discoveries that are being done as well as the ROV research.

Wilcox, C. July 1, 2013. The Worst Marine Invasion Ever. The Slate Group. http://www.slate.com/articles/health_and_science/science/2013/07/lionfish_invasion_the_invasive_fish_are_eating_so_many_native_species_that.html . Accessed: 3/17/2014.

This article written by Christie Wilcox is about the worst marine invasion ever, which is the invasion of the lionfish. Christie came to North Carolina to study the lionfish invasion and met up with James Morris, who works at the National Ocean Service's Center for Coastal Fisheries and Habitat Research in Beaufort, North Carolina. James has discovered "white chunky stuff" inside lionfish he has caught and dissected along the coast of North Carolina and has concluded that these lionfish are obese. And this is because lionfish eat everything in sight and have no natural predators in the Atlantic Ocean. It was once thought that lionfish arrived to these waters from coastal damage caused by Hurricane Andrew; however, it is now believed that individuals who bought them from aquariums began to release them in the wild and thrived and started a new population. This article contains great detail about the studies being conducted in order to make lionfish part of the fisheries in North Carolina in order to help control the invasive population.

*Williams, N. 2010. Major lionfish hunt launched. *Current Biology* 20: R1005-R1006.

This journal article discusses the Red Lionfish, which is native of the eastern Pacific, appears to be spreading rapidly around Florida. The Lionfish are making their way up the eastern seaboard and the Caribbean. This is growing alarm for many marine biologists. They feed on native coral reef species, which worries conservationists. They have venomous spines, which seem to scare off most potential predators.

Brandi Summerlin

Adams, J. December 9, 2013. Lionfish Invasion! *Science World* 70(6): 20-22.

The article titled "Lionfish Invasion" opens by talking about lionfish when they first appeared in Florida and why the Reef Environmental Education Foundation (REEF) felt that they must act fast. A thorough history of the lionfish invasion is given in the article and the discussion of their venomous spines and predation are also covered in the article.

Anonymous. Jan. 22, 2014. War on invasive lionfish in Atlantic waters yields first good news. United Press International, Inc. http://www.upi.com/Science_News/2014/01/22/War-on-invasive-lionfish-in-Atlantic-waters-yields-first-good-news/UPI-79821390428352/. Accessed 04/11/14.

The website listed above takes a different approach on the lionfish stance. The population of lionfish soared to the top of the charts before they could be stopped but this article talks about control. By controlling these populations of lionfish, it would allow for recovery of native fish biomasses that have recently fell victim to the lionfish invasion.

Anonymous. January 23, 2014. The Lionfish Invasion: Invasive lionfish threaten native fish and the environment in U.S. Atlantic coastal waters. National Oceanic and Atmospheric Administration. <http://oceanservice.noaa.gov/facts/lionfish.html>. Accessed 04/11/14.

The above website is sponsored by NOAA. The introduction of lionfish, the geographical spread of the invasive lionfish, the effects that lionfish will have on other species and various ecosystems, as well as the conventional methods of controlling lionfish are a few topics mentioned in this article. More research is something that definitely needs to keep being done because it helps scientists learn and better understand the potential threat that these lionfish present to key reefs and the commercial fishing industries.

Bald, L. October 20, 2013. Lionfish invasion: Atlantic Ocean faces growing epidemic of Lionfish infestation. Examiner.com. <http://www.examiner.com/article/lionfish-invasion-atlantic-ocean-faces-growing-epidemic-of-lionfish-infestation>. Accessed 04/12/14.

While some of the articles have mentioned that lionfish can have a negative impact on coral reefs systems this article actually says that they are able to quickly wipe out 90 percent of a reef's population since they have little-to-no predators. The article tells us that the reason why these lionfish are so invasive and so fast-evolving is because they are able to fertilize after only 12 months of life and when they reproduce they lay between 30,000 to 40,000 eggs every few days. This really does show that these lionfish are incredibly invasive and a rapidly growing epidemic with no current solutions in sight.

Duffie, C.J. April 10, 2014. Inaugural Southwest Florida Lionfish Derby This Weekend. Captivasanibel.com. http://www.island-reporter.com/page/content_detail/id/523696/Inaugural-Southwest-Florida-Lionfish-Derby-this-weekend.html?nav=5064. Accessed 04/11/14.

The website above talks about the Inaugural Lionfish Derby. The article talks lays out a strategic plan for individuals participating in the event. On this day, during this event, the article talks about how only lionfish can be caught and it talks specifically about how they may be caught (i.e. hook and line, hand-held net, pole spear, etc...). In addition, prizes are offered as incentives for people to go out and participate in this organized event. The article also mentioned that the capture lionfish will only be used for the point of understanding population studies.

*Frazer, T.K, C.A. Jacoby, M.A. Edwards, S.C. Barry and C.M. Manfrino. 2012. Coping with the Lionfish Invasion: Can Targeted Removals Yield Beneficial Effects? *Reviews in Fisheries Science* 20(4):185-191.

The primary literature article listed above focuses on the idea of maintenance management in response to the lionfish invasion. We learn that while avoiding impacts from invasive species and early detection is important, it is more significant to prevent these introductions in the first place. The article also talks about the environmental and economic costs associated with these invasions. While we often think of the environmental impacts, it is important to also consider the economics and think how

much money will be put into controlling the population of these invasive species since they have already been introduced.

Gannon, M. July 25, 2013. Lionfish found at sunken ship 300 feet below water's surface wreaking havoc. Foxnews.com. <http://www.foxnews.com/science/2013/07/15/lionfish-found-at-sunken-ship-300-feet-below-water-surface-wreaking-havoc/>. Accessed 04/12/14.

Reproduction in lionfish is a common problem associated with the rapidly evolving numbers of this species, however, this article talks about how, as of recently, these lionfish are seen at greater, unexpected depths, as in some cases up to 300 feet below the water's surface as in this article. We learn that researchers are still trying to get a better understanding of these species in the Pacific Ocean (their original habitat) so that they might stop the Atlantic invasion.

*Green S.J., J.L. Akins, A. Maljković, and I.M. Côté. March 7, 2012. Invasive Lionfish Drive Atlantic Coral Reef Fish Declines. PLoS ONE 7(3):1-3.

While it is known that the lionfish will have an impact on marine ecosystems, we learn in this article that the relative size of these impacts has yet to be determined. Nine different coral reefs off New Providence Island, Bahamas are observed and this article indicates the findings. The article uses data to predict a correlation between the abundance of lionfish and the biomass of their prey over a period of time. Without any effective control management plans set into place the lionfish communities will continue to rise, leading to possible, negative long term impacts on Atlantic marine communities.

Harrell, S. 2014. Lionfish Facts. World Lionfish Hunters Association. <http://lionfish.co/lionfish-facts/>. Accessed 04/11/14.

The website above is responsible for providing a comprehensive list of facts about the invasive lionfish. The facts on the site are provided as to address the general public and make them aware of the current issue. Ciguatera, a toxin seen in lionfish specific to very few areas, is mentioned in the list of facts, however, it is stated that lionfish are not poisonous, can be consumed, and there has been no evidence of ciguatera food poisoning after eating lionfish at this point in time. Overall, the website does a very good job of breaking down a rather complex topic.

*Lesser, M.P. and M. Slattery. April 28, 2011. Phase shift to algal dominated communities at mesophotic depths associated with lionfish (*Pterois volitans*) invasion on a Bahamian coral reef. Biological Invasions (2011) 13:1855–1868.

This article speaks specifically about the definite, negative impacts that have occurred in shallow coral reef fish populations due to the invasive lionfish. Herbivores and biodiversity in general, at 91 meters depth, has been also been affected due to this fast-spreading invasive fish. Tests were performed to ensure that coral bleaching, overfishing, hurricanes, or disease were not the cause of shifts in mesophotic coral reefs and the

changes affecting benthic community structure. It is questionable if these coral reefs or these communities have the resilience to recover after the damage that has been caused.

Meerschaert, K. March 27, 2014. Month-Long Hunt For Invasive Lionfish Set To Begin. WJCT News. <http://news.wjct.org/post/month-long-hunt-invasive-lionfish-set-begin>. Accessed 04/12/14.

This article opens by talking about a local group of individuals heading out to search for and kill the lionfish, an invasive species to the Atlantic waters. A month long tournament that encourages others to go out and hunt these fish down is mentioned in the article. The incentive for most people is the prizes that will be given out to the most caught. In addition, the lionfish are said to have a tastier, cleaner meat that many people prefer.

*Morris, J.A., A. Thomas, A.L. Rhyne, N. Breen, L. Akins, and B. Nash. April 2011. Nutritional properties of the invasive lionfish: A delicious and nutritious approach for controlling the invasion. *Aquaculture, Aquarium, Conservation & Legislation International Journal of the Bioflux Society* 4(1): 21-26.

While many other articles present the idea of maintenance management and other various control strategies, this article talks specifically about promoting lionfish as a food fish and using this as a control strategy. In addition to the tastier, clean meat of lionfish they are also said to provide high concentrations of n-3 polyunsaturated fatty acids, which provide all sorts of health benefits. The study that was done and presented in this article aims to compare lionfish to other marketplace fishes and document their fatty acid profiles, find the fillet yield of lionfish, and use the lionfish and market reef fish to perform a preliminary sensory comparison.

Sezen, U. April 10, 2014. Invasive Lionfish of the Tropical Atlantic – Marine Ecology Expeditions – Lorenzo Mittiga (2012). [Naturedocumentaries.org](http://naturedocumentaries.org). <http://naturedocumentaries.org/5344/invasive-lionfish/>. Accessed 04/12/14.

After giving a brief introduction to the two types of lionfish that have been introduced off the coast of the eastern US, the website talks about the densities of these fish and how in certain places the density of these fish could be more than eight times higher than the original densities found from the lionfish's native range. The website listed above also contains a bunch of different videos about lionfish. In one of the videos we actually see a diver going out trying to capture a lionfish and there is also an instructional video on how to properly fillet a lionfish.

Wilcox, C. July 1, 2013. The Worst Marine Invasion Ever. The Slate Group. http://www.slate.com/articles/health_and_science/science/2013/07/lionfish_invasion_the_invasive_fish_are_eating_so_many_native_species_that.3.html. Accessed 04/11/14.

The website listed above talks about this idea of “eat them to beat me” in reference to the lionfish. There seems to be no known way to combat or control these invasive species so

the writer encourages other to “pit our bottomless stomachs against theirs”. While it seems like an ideal concept on paper, it is more difficult due to the fact that these lionfish don’t simply bite a hook and line. To catch them, it usually requires individuals to go out and spear them one by one. In some areas, such as the Virgin Islands, there is also concern from the Federal Drug Administration (FDA) that these lionfish might contain ciguatera. While the idea of eradication seems far-fetched at this point, many are urging others to understand more that we can manage these lionfish and potentially minimize the damage that they are putting on our marine ecosystems.

Wurzbacher, J. September 2011. The Lionfish Invasion. Sailors for the Sea.

<http://sailorsforthesea.org/resources/ocean-watch-essays/lionfish-invasion>. Accessed 04/12/14.

The website listed above covers topics such as: how did the lionfish get here, what’s the harm, and what can be done about this? A map showing the distribution of lionfish in the Atlantic Ocean is also available at this source. At the end of the article there is some tips provided urging others to take action. One of the tips provided is to report sightings of any lionfish to REEF to help track and monitor this invasion.

Travis Tobin

*Albins, M., and M. Hixon. September, 11, 2008. Invasive Indo-Pacific lionfish *Pterios volitans* reduce recruitment of Atlantic coral reef fishes. Marine Ecology Progress Series 367:233-238.

This was an experiment done to see the effect of lionfish on recruitment of native reef species in the Bahamas. The experiment found that lionfish reduce recruitment significantly of native reef fishes. Over five weeks they found that lionfish reduced recruitment of native reef fishes by 79%.

Associated Press. August 13, 2008. Invader gobbling up East Coast, Caribbean fish. NBC News. Available: http://www.nbcnews.com/id/26184738/ns/world_news-world_environment/t/invader-gobbling-east-coast-caribbean-fish/#.U0sE7Nwuods. Accessed 4/13/14.

This article describes the extent of the invasion and how bad it is along the east coast of the U.S. A marine ecologist is quoted in saying, “this may very well become the most devastating marine invasion in history.” It also talks about lionfish predators. It is quoted in the article that Andy Dehart from the National Aquarium in Washington has successfully gotten sharks to eat lionfish.

Greenberg, P. July 2011. Lionfish Invasion: A Guide to Hunting and Fishing. Food & Wine. Available: <http://www.foodandwine.com/articles/lionfish-invasion-a-guide-to-hunting-and-fishing>. Accessed 4/14/14.

A diver that enjoys diving for lionfish writes this article and he expresses the reward of it. There is a section in the article called “Creating a Market” which will be a big help to our debate team. He talks about how good the lionfish tastes and how people are working with restaurants all over to try and help promote lionfish as food fish.

Huus, K. August 10, 2010. Do your civic duty: Eat this fish! NBC News. Available: http://www.nbcnews.com/id/38632799/ns/us_news-environment/t/do-your-civic-duty-eat-fish/#.U0xM1twuods. Accessed: 4/14/14.

This article talks about trying to inform people of the lionfish invasion and ways to promote hunting and fishing for lionfish. It talks about the lionfish derbies going on in different places trying to control the species. It also mentions how NOAA is striving to promote a series of lionfish events at restaurants throughout the country trying to create a demand for lionfish.

*Kimball, M., J. Miller, P. Whitfield, and J. Hare. November 30, 2004. Thermal tolerance and potential distribution of invasive lionfish (*Pterios volitans/miles* complex) on the east coast of the United States. Marine Ecology Progress Series 283:269-278.

This paper was written by conducting three different experiments to obtain information on the thermal tolerance of lionfish and what water temperatures they can endure. The first experiment conducted was to see if the lionfish could tolerate normal decrease in temperatures off the southeastern US. The second experiment was on fast rates of temperature decline and how they affected the lionfish. The last experiment looked at acclimation of cold temperatures by the lionfish.

Linendoll, K. October 19, 2013. Lionfish infestation in Atlantic Ocean a growing epidemic. CNN. Available: <http://www.cnn.com/2013/10/18/tech/innovation/lionfish-infestation-atlantic-linendoll/>. Accessed 4/14/14.

This author talks about her experience diving on a lionfish hunt. She mentions how the lionfish just sat there not intimidated at all, not affected by the human presence. She also interviewed James Morris from NOAA in this article.

Loller, K. May 13, 2012. Are predators eating lionfish? Southwest Florida fishermen find a grouper that appears to have eaten the invasive species. News-Press. Available: <http://www.news-press.com/article/20120514/GREEN/305140006/Are-predators-eating-lionfish->. Accessed 4/13/14.

This is a very interesting article that tells the story of a group of fishermen that were catching grouper off the coast of Florida. After catching one, they noticed it had coughed

up a lionfish. This article talks about how this is proof that lionfish do have predators, one of them being the grouper.

McNab, M. September 8, 2013. Invasive lionfish population booming on East Coast, making species popular food choice. The Island Packet. Available: <http://www.islandpacket.com/2013/09/08/2673392/growing-east-coast-lionfish-population.html>. Accessed 4/13/14

This article talks about how lionfish are becoming more popular to eat along the east coast. The author describes how lionfish are hurting grouper and snapper populations. It is described in the article that the lionfish have to be specially prepared and that more chefs along the east coast are finding out about the lionfish.

*Morris Jr., J., and J. Akins. October 27, 2009. Feeding ecology of invasive lionfish (*Pterios volitans*) in the Bahamian archipelago. Environ Biol Fish 86:389-398.

This was a study done to look at the feeding ecology of lionfish. Stomach content was collected from lionfish taken throughout the Bahamian archipelago. They found that lionfish prey on a number of different teleost's and crustaceans. Another thing they found in the study is that lionfish fed mostly in the morning hours.

*Schofield, P. September 1, 2009. Geographic extent and chronology of the invasion of non-native lionfish (*Pterios volitans* [Linnaeus 1758] and *P. miles* [Bennett 1828]) in the Western North Atlantic and Caribbean Sea. Aquatic Invasions 4(3):473-479.

This is a paper done to show the chronology of the lionfish invasion from the Caribbean all the way up through the Atlantic. It has great figures in it to show how the lionfish invasion has spread rapidly throughout the Atlantic.

Talton, T. June 24, 2013. Lionfish Tournament: If You Can't Beat 'Em, Eat 'Em. North Carolina Coastal Federation. Available: <http://www.nccoast.org/article.aspx?k=6427ca4e-9edb-4454-95b4-ae28f62d8fa3>. Accessed 4/14/14.

This article talked about the success of the first lionfish spearfishing tournament held in Morehead City last summer. It mentions how they are excited that they are seeing lionfish control in other parts of the world and that it is possible. The lionfish caught in the tournament were prepared for free for the people that were attending the Big Rock Blue Marlin tournament.

Wheatly, Anne. 2008. Lionfish: Where are they now? NC Sea Grant. Available: <http://www.nceseagrants.org/home/coastwatch/coastwatch-articles?task=showArticle&id=606>. Accessed: 4/14/14.

This article gives a background of lionfish invasion but also talks about ROV (Remotely operated vehicles) research. These allow for research to be done at depths that cannot be reached by divers. These vessels are equipped with cameras and equipment that can measure temperature, depth, light transmission, and oxygen.

*Whitfield, P., J. Hare, A. David, S. Harter, R. Munoz, and C. Addison. June 4, 2006. Abundance estimates of the Indo-Pacific lionfish *Pterios volitans/miles* complex in the Western North Atlantic. *Biol Invasions* 9:53-64.

This was a study done in 2006 to estimate the magnitude of the lionfish invasion. They also estimated grouper abundance to compare to lionfish abundance. They did two different types of studies. One by scuba divers that did visual surveys off the North Carolina coast and then studies done by a remote operated vehicle at five locations from Florida to North Carolina. They found that lionfish abundance in these locations were only second to the scamp grouper.

Wilcox, C. July 1, 2013. The Worst Marine Invasion Ever. Available: http://www.slate.com/articles/health_and_science/science/2013/07/lionfish_invasion_the_invasive_fish_are_eating_so_many_native_species_that.3.html. Accessed 4/13/14.

This article describes the lionfish as the worst marine invasion ever. It includes great numbers on the lionfish invasion and the effects it has had on other reef species. The author says that when the lionfish arrives on a reef, it can reduce the native fish populations by up to 70 percent. It also mentions the “Lionfish Derby” in North Carolina, which is designed to help reduce lionfish populations by having a tournament for divers. The author participated in that and describes the experience and the numbers of lionfish they saw.

Wurzbacher, J. September 2011. The Lionfish Invasion. Sailors for the Sea. Available: <http://sailorsforthesea.org/resources/ocean-watch-essays/lionfish-invasion>. Accessed 4/12/14.

This article gives very detailed background information on the issue of the lionfish invasion. The author describes how lionfish became an issue and why the lionfish invasion is bad for our waters. At the end of the article she describes possible solutions to the problem, and how to try to control populations of lionfish.

Adrian Vu

Bleier, E. October 21, 2013. Lionfish invasion is threatening the Atlantic Ocean. United Press International. http://www.upi.com/Science_News/2013/10/21/Lionfish-invasion-is-threatening-the-Atlantic-Ocean/9321382363683/ Accessed April 14, 2014.

This website starts off by giving a description of the problem at hand, which is the lionfish invasion. It also mentions the effects that lionfish can have on the coast if allowed to continue to populate the area.

Florida Fish and Wildlife Conservation Commission. No Date. Lionfish – *Pterois Volitans*. Florida Fish and Wildlife Conservation Commission. <http://myfwc.com/wildlifehabitats/nonnatives/marine-species/lionfish/> Accessed April 14, 2014.

This website has information on not only the physical features of the lionfish, but also the areas it impacts. There are also pictures on the website that show areas affected by lionfish and the pictures also have dates so you can see when the lionfish population really started to flourish.

Gupta, A. May 8, 2009. Invasion of the Lionfish. Smithsonian.

<http://www.smithsonianmag.com/science-nature/invasion-of-the-lionfish-131647135/> Accessed April 13, 2014.

This article gives a description of the lionfish problem. It also mentions information about lionfish such as the habitats that lionfish live in, the size that lionfish usually grow to, and what lionfish generally eat on average. The article also mentions actions and events that have taken place over the years as it pertains to lionfish.

*Hare, J. A., and P. E. Whitfield. 2003. An integrated assessment of the introduction of lionfish (*Pterois volitans/miles* complex) to the western Atlantic Ocean. National Oceanic and Atmospheric Administration Technical Memorandum.

This article talks about the background of the lionfish invasion and briefly of how they believe it started. It also talks about some of the areas where the lionfish have been spotted. It talks about management actions that had been taken at the time, the consequence of not taking action, effects on the ecosystem, and possible encounters with the fish and divers or fishers.

*Kimball, M. E., J. M. Miller, P. E. Whitfield and J. A. Hare. November 30, 2004. Thermal tolerance and potential distribution of invasive lionfish (*Pterois volitans/miles* complex) on the east coast of the United States. Marine Ecology Progress Series. 283(No Issue): 269-278.

This article talks about how the lionfish is the first invasion of a Pacific marine fish in the Atlantic Ocean. This article focuses on one of the reasons they believe the lionfish invasion is possible, which is the temperature of the water. The article also talks about why even though the temperature allows the lionfish to be in the Atlantic it also limits the range they can go in the Atlantic.

Linendoll, K. October 19, 2013. Lionfish infestation in Atlantic Ocean a Growing Epidemic. CNN. <http://www.cnn.com/2013/10/18/tech/innovation/lionfish-infestation-atlantic-linendoll/> Accessed April 13, 2014.

This article highlights the lionfish invasion problem and how it can get worse if no action is taken. At the current rate of lionfish population increase it is predicted to have a negative impact on the environment. The article also talks about the actions that have already been taken such as hunting the lionfish.

McFadden, D. April 13, 2014. Jamaica Reports Big Drop in Lionfish Sightings. ABC News. <http://abcnews.go.com/International/wireStory/jamaica-reports-big-drop-lionfish-sightings-23311015> Accessed April 14, 2014.

This article talks about how there has been a decline in lionfish sighting in Jamaica. The article highlights what steps they took in order to help remove lionfish from the water. This article is helpful because management efforts can be modeled after Jamaica to help with the lionfish invasion.

*Morris, J. A., Jr. 2012. Invasive Lionfish: A Guide to Control and Management. Gulf and Caribbean Fisheries Institute Special Publication.

This source talks about the lionfish problem, how it came to be, how it is affecting us now, and how it will affect us in the future. This also mentions ways to educate people on the lionfish problem, strategies to control the problem, ways to monitor the problem and legal considerations for the management of lionfish.

*Morris, J. A., Jr. and J. L. Akins. November 2009. Feeding Ecology of Invasive Lionfish (*Pterois Volitans*) in the Bahamian Archipelago. Environmental Biology of Fishes. 86(3): 389-398.

This article talks about the eating habits of the lionfish. The stomach contents from lionfish were taken and examined to see what different things lionfish consume. Knowing what lionfish consume will help you determine what kind of effect they can have to the species they prey upon and so management plans can then be determined to reduce ecological effects of lionfish.

*Mumby P. J., A. R. Harbone and D. R. Brumbaugh. Grouper as a Natural Biocontrol of Invasive Lionfish. PLoS ONE. 6(6): 1-4.

This article talks about how the lionfish have invaded much of the Caribbean and how they have negatively affected the area. This article focuses on how Caribbean groupers have been known to eat the lionfish, which gave scientists the idea of trying to use groupers to control the population of lionfish. They also mention problems with using these groupers as a predator of lionfish, however these predators need to be looked into as a possible option to reduce lionfish population.

National Geographic. No Date. Lionfish. National Geographic.

<http://animals.nationalgeographic.com/animals/fish/lionfish/> Accessed April 14, 2014

This website just provides some facts about the lionfish. Some of the things about the lionfish that are mentioned are its size, weight, life span, diet, its appearance, and its defense mechanism.

NOAA (1). No Date. Invasive Species. National Oceanic and Atmospheric Administration.

<http://coastalscience.noaa.gov/research/pollution/invasive/> Accessed April 13, 2014.

This article highlights the effects and impacts of invasive species on the U.S. coast. They also provide ways to predict and control the spread of invasive species.

NOAA (2). No Date. Lionfish Biology Fact Sheet. National Oceanic and Atmospheric Administration. <http://oceanservice.noaa.gov/education/stories/lionfish/factsheet.html> Accessed April 14, 2014.

This website gives you information about the lionfish. Some of the information given includes different names for the lionfish, where they natively reside, non-native areas they are at, habitats, and much more.

NOAA (3). No Date. The Lionfish Invasion: Invasive lionfish threaten native fish and the environment in U.S. Atlantic coastal waters. National Oceanic and Atmospheric Administration. <http://oceanservice.noaa.gov/facts/lionfish.html> Accessed April 13, 2014.

This article provides a background on the lionfish invasion, where the lionfish reside, and the impact the non-native species will have on the ecosystem.

Waite, R. August 29, 2011. Lionfish Invasion Threatens Coral Reefs in the Atlantic and Caribbean. World Resources Institute. <http://www.wri.org/blog/lionfish-invasion-threatens-coral-reefs-atlantic-and-caribbean> Accessed April 14, 2014.

This website gives a brief description of the lionfish invasion problem. The website also includes pictures of the areas lionfish started to invade over a 10 year period so you'll be able to see not only the areas affected, but also the rate at which they affect the area. Ways the lionfish are affecting the areas they are invaded are mentioned as well as management plans that have been discussed.

Takeisha Ward-Revised

*Albins, M.A., and M.A. Hixon. 2013. Worst case scenario: potential long-term effects of invasive predatory lionfish (*Pterois volitans*) on Atlantic and Caribbean coral-reef communities. *Environmental Biology of Fishes* 96:1151-1157. <http://link.springer.com/article/10.1007/s10641-011-9795-1>. Accessed 04/14/2014.

This source tells us how the red lionfish has recently invaded Western Atlantic and Caribbean coral reefs, and may be one of the most ecologically harmful marine fish introductions to date. It talks about their broad suite of traits that makes them successful invaders. This source describes a possible "worst case scenario" where the direct and indirect effects of lionfish could combine with the impacts of preexisting stressors and cause substantial deleterious changes in coral reef communities.

*Barbour, A.B., M.L. Montgomery, A.A. Adamson, E. Diaz-Ferguson, and B.R. Silliman. 2009. Mangrove use by the invasive lionfish *Pterois volitans*. *Marine Ecology Progress Series* 401:291-294. <http://www.cabdirect.org/abstracts/20103105302.html;jsessionid=3F38C2E9020EAF0633F2993BD2889C3E> . Accessed 04/14/2014.

This source tells us about how lionfish are successful invasive predators in the sun-tropical and tropical Western Atlantic. Their invasion of the coral reef ecosystem is a major conservation concern. The effects of lionfish on coral reef communities have been examined, but it is not known if these predators use critical non-reef habitat such as mangroves, which are nurseries for many reef fish species. To investigate lionfish usage of this, they compared population size structure and stomach contents.

*Johnston, M.W., and S.A. Purkis. 2011. Spatial analysis of the invasion of lionfish in the western Atlantic and Caribbean. *Marine Pollution Bulletin* 62:1218-1226
<http://www.sciencedirect.com/science/article/pii/S0025326X11001718>. Accessed 04/14/2014.

This source talks about *Pterois volitans* and *Pterois miles*, two sub-species of lionfish that have become the first non-native, invasive marine fish along the U.S. Atlantic coast and Caribbean. The route and timing of the invasion is poorly understood, but sightings and captures have been documented since their introduction. This source analyzes these records based on spatial location, dates of arrival, and prevailing physical factors at the capture sights.

Lionfish Hunters. No date. Danger Surrounding the Venomous Lionfish Sting.
<http://www.lionfishhunters.org/Danger.html> . Accessed 04/14/2014.

This source tells us about how venomous lionfish are. It says they are one of the most venomous fish on the ocean floor, ranking them second to stingrays. They have a total number of stinging's worldwide estimated about 40,000-50,000 cases annually. It also goes into pre-hospital care and Emergency department care.

McNab, M. 09/08/2013. The Island Packet. Invasive population booming on East Coast, making species popular food choices. <http://www.islandpacket.com/2013/09/08/2673392/growing-east-coast-lionfish-population.html> . Accessed 04/14/2014.

This source tells us that ecosystem-damaging lionfish species along the coast have almost exponentially grown to the point where some have proposed to eat them as a way of combat. They have found lionfish to be damaging to reefs along the East Coast and also to snapper and grouper because they eat the same food.

*Morris, J. 08/07/2009. The biology and ecology of the invasive Indo-Pacific lionfish. Dissertation NCSU Libraries. <http://www.lib.ncsu.edu/resolver/1840.16/3983> . Accessed 04/14/2014.

This source tells us about the Indo-Pacific Lionfish. Prior to their invasion, little was known regarding the biology and ecology of lionfish. This source provides a synopsis of chronology, taxonomy, local abundance, reproduction, early life history and dispersal, venomology, feeding ecology and much more. It also says that future research is needed

to understand the scale of impacts that lionfish could cause, especially in coral reef ecosystems, which are already heavily stressed.

N.C. Division of Marine Fisheries. No Date. Lionfish Alert. NCDENR.org
<http://portal.ncdenr.org/web/mf/lionfish-alert>. Accessed 04/14/2014.

This source tells us that lionfish are often kept in both public and private aquariums. Lionfish have been observed by scuba divers in corals, rocky and artificial reefs along the southeast coast. Recently they have also been caught by bottom-fishing anglers. There is increasing concern that since they have no natural enemies, they may adversely impact natural fish populations. Also it talks about their venomous spine.

NOAA Ocean service education. 05/09/2011. The Lionfish Invasion. Ocean Service.
http://oceanservice.noaa.gov/education/stories/lionfish/lion02_inva.html. Accessed 04/14/2014.

This source is about the sightings of lionfish and when they were first spotted off the coast of North Carolina. Their theory is that lionfish, a popular aquarium fish, were likely released on purpose when people no longer wanted them as aquarium pets. Then the warm Gulf Stream most likely transported buoyant lionfish eggs and larvae from Florida northward, which aided their Atlantic Journey.

Price, J. 04/23/2009. Alien lionfish swarm N.C. coast. Phys.org.
<http://phys.org/news159706864.html>. Accessed 04/14/2014.

This source is about how lionfish are swarming North Carolina's coast. If you go deeper than 100 feet, they are ubiquitous. They are also eating everything, including reefs. It also talks about how lionfish have a sweet, white meat, similar to the groupers and snappers. Scientists and divers hope to persuade restaurants in the area to start serving lionfish.

Spencer, E. 08/08/2013. The Truth About Getting Stung by a Lionfish. National Geographic.
<http://newswatch.nationalgeographic.com/2013/08/08/the-truth-about-getting-stung-by-a-lionfish/>. Accessed 04/14/2014.

This source tells us about the truth behind getting stung by a lionfish. It won't kill you, but it will make you wish you were dead. Stings can be easily avoided by proper handling techniques and safety measures. Lionfish only use their weapons defensively. If you are stung, a loose sheath surrounding each spine is pushed down which compresses two venom glands located down the length of the spine. The venom then travels through two grooves up the spine and into the wound. It also talks about lionfish safety and what to do if you are stung.

Talton, T. 06/24/2013. Lionfish Tournament: If you Can't Beat 'Em, Eat 'Em. North Carolina Coastal Federation. <http://www.nccoast.org/article.aspx?k=6427ca4e-9edb-4454-95b4-ae28f62d8fa3> . Accessed 04/14/2014.

This source is about management of lionfish. Although eradication is highly unlikely because of the fact that they are hard to catch and have no local predators, success stories are emerging about lionfish control. Lionfish are voracious eaters capable of thinning out populations of native fish. Efforts are being made to help control them so are training scuba divers to go out and collect them, and spearfishing tournaments.

UNC-TV. 04/14/2014. Lionfish. <http://science.unctv.org/content/lionfish> . Accessed 04/14/2014.

This source starts out comparing lionfish invasion to Kudzu, a plant species brought to the United States for erosion control, but ended up growing incredibly fast. It didn't have any natural predators in the area and it out competed native trees and shrubs by climbing over them and killing them because of heavy shading. Just like Kudzu, lionfish are outcompeting the native species in their environment. It also talks about how they got there and when they were first spotted.

Brenna Wells

*Albins, M. A. and P. J. Lyons. 2012. Invasive red lionfish *Pterois volitans* blow directed jets of water at prey fish. Marine Ecology Progress Series 448: 1-5.

Field and lab studies have been done to see how the red lionfish hunts and behaves with other organisms. The lionfish slowly approaches its prey and blows a stream of water at its prey, stunning it, it then strikes the prey and swallows it after one strike. This behavior shows a high level of predatory efficiency.

Hudson, J. 2013. Belize Fights Back Against an Uninvited Guest. National Geographic. <http://newswatch.nationalgeographic.com/2013/09/27/belize-fights-back-against-an-uninvited-guest/>. Accessed 04/14/14.

The Caribbean have started taking action against their invasion of lionfish. Their tourism market is way too valuable to their economy to have it be jeopardized by the lionfish. They are working on teaching fishermen on how to properly and safely catch and process the lionfish so that they can sell it at the market and make a profit off of their catch. Even though they have been given the okay to fish for lionfish, fishermen are still weary of going after a fish with so many poisonous spines.

Florida Fish and Wildlife Conservation Commission. No date. Lionfish (*Pterois volitans*, *Pterois miles*) Frequently Asked Questions. Florida Fish and Wildlife Conservation Commission. <http://myfwc.com/wildlifehabitats/nonnatives/marine-species/lionfish/faqs/#12>. Accessed 04/14/14.

The FWC put out this FAQ so that everybody could get some general facts about lionfish. This helps make the public aware of the issue. It also lets people know how to be safe when handling the fish. Information is given for filing reports of spotting lionfish.

Greenberg, P. No date. Lionfish Invasion: A Guide to Hunting & Fishing. Food and Wine. <http://www.foodandwine.com/articles/lionfish-invasion-a-guide-to-hunting-and-fishing>. Accessed 04/14/14.

Greenberg writes in his article about how the lionfish should be hunted and eaten because they eat all of the pretty reef fish and they can re-populate an area so quickly that we couldn't make them endangered. He says that the only real way to catch them is to dive and catch them with either a net or a spear. He says that the sting is awful from the fish, but their meat is actually quite tasty. The poison in their spines is denatured when heated above 350 degrees, and once the spines are clipped off the fish are safe to handle and eat. He talks from a civilian standpoint, not so much a scientist.

Gupta, A. 2009. Invasion of the Lionfish. Smithsonian Magazine. <http://www.smithsonianmag.com/science-nature/invasion-of-the-lionfish-131647135/?no-ist>. Accessed 04/14/14.

It took only three lionfish to start the invasion and they laid hundred of eggs. These eggs released larvae that turned into adults that can breed ever 55 days during all times of the year. Lionfish are the first exotic species to invade coral reefs. How quickly the multiply is almost unheard of in marine history. They grow to be a foot long and have sharp venomous spines. To feed lionfish herd smaller fish into pockets of coral reef or up against barriers and then swallow the prey in a single bite.

*Morris, J. A., J. L. Akins, A. Barse, D. Cerino, D. W. Freshwater, S. J. Green, R. C. Munoz, C. Paris, and P. E. Whitfield. 2009. Biology and Ecology of the Invasive Lionfishes, *Pterois miles* and *Pterois volitans*. Gulf and Caribbean Fisheries Institute 61: 1-5.

This journal goes into great detail about every aspect of the lionfish. How they reproduce, their life history and stages, the kind of venom they have and how it affects organisms, taxonomy, anything you could want to know about lionfish is covered. It even talks about how to control the populations.

*Muñoz R. C., C. A. Currin, and P. E. Whitfield. 2011. Diet of invasive lionfish on hard bottom reefs of the Southeast USA: insights from stomach contents and stable isotopes. Marine Ecology Progress Series 432:181-193.

While the lionfish is becoming a major issue along the Atlantic coast, its biology and ecology is only starting to be understood. Not much is known about this species, except that it is a very invasive species. This journal talks about what the lionfish eats, and where it lives.

NCDENR. No date. Lionfish Alert. Division of Marine Fisheries.
<http://portal.ncdenr.org/web/mf/lionfish-alert>. Accessed 04/14/14.

The NCDENR gives some general information about lionfish, where they live, what parts of them are poisonous, and how they have been caught. It is given mostly as a warning to divers and fisherman in case they come across them.

NOAA. No date. Lionfish from Sea to Table. NOAA.gov.
<http://sanctuaries.noaa.gov/qr/lionfish/>. Accessed 04/14/14.

The NOAA gives a quick and condense guide to lionfish. It tells you how to capture, clean, and prepare them safely. It also says what to do if you do get stung.

NOAA. No date. The Lionfish Invasion. NOAA.gov.
<http://oceanservice.noaa.gov/facts/lionfish.html>. Accessed 04/14/14.

It is unknown exactly how the lionfish got to the Atlantic coast, but they are a major issue. They are now well established along the U.S., the Caribbean, and in parts of the Gulf of Mexico. Lionfish are not native to the Atlantic coast so they have very few predators, but they feed on anything they can find. It is not yet determined how the invasion of lionfish will affect the coast or the commercial fishing industry.

Wilcox, C. 2013. The Worst Marine Invasion Ever. Slate.com.
http://www.slate.com/articles/health_and_science/science/2013/07/lionfish_invasion_the_invasive_fish_are_eating_so_many_native_species_that.html. Accessed 04/14/14.

This article talks about how the lionfish they are finding off of NC are not just fat, they are obese. The fish have so much intestinal fat that there are signs of liver damage. Wilcox says that when lionfish arrived they spread like locusts, eating their way from NC to Venezuela. When they arrive at a reef they reduce the fish population by 70%. The amount of lionfish increased 700% between 2004 and 2008.

*Whitfield, P. E., A. W. David, J. A. Hare, S. L. Harter, R. C. Munoz, and C. M. Addison. 2007. Abundance estimates of the Indo-Pacific lionfish *Pterois volitans/miles* complex in the Western North Atlantic. *Biological Invasions* 9: 53-64.

The lionfish spread from Florida to up the southeast coast of the U.S. in less than a decade. Lionfish were more abundant in shallower waters off of NC. A good way to assess how many lionfish are around is to count the population of grouper, since lionfish tend to eat the grouper off of NC coast. The high number of lionfish present is a danger for the local ecosystems.

*Whitfield, P. E., T. Gardner, S. P. Vives, M. R. Gilligan, W. R. Courtenay Jr., G. C. Ray, and J. A. Hare. 2002. Biological invasion of the Indo-Pacific lionfish *Pterois volitans* along the Atlantic coast of North America. *Marine Ecology Progress Series* 235: 289-297.

Adults were collected off the coasts of NC, Georgia, and Florida while juveniles were collected along the shore of Long Island, New York. Fish have also been found around Bermuda. The distribution of adults suggests that lionfish are surviving under extreme water conditions, which makes them even more invasion and harder to control.

Wurzbacher, J. 2011. The Lionfish Invasion. Sailors for the Sea.

<http://sailorsforthesea.org/resources/ocean-watch-essays/lionfish-invasion>. Accessed 04/14/14.

Wurzbacher talks about why the invasion of lionfish is bad, and exactly how they affect the reefs. She says that there are not any solutions, but the only thing that can currently be done is controlling the population already in existence. In the pacific, sharks and groupers eat lionfish, but that is not the current case in the Atlantic.

Quist, K. 2011. Lionfish May Have Value as Seafood Catch. Keys Info Net.

<http://www.keysnet.com/2011/08/05/365463/lionfish-may-have-value-as-seafood.html>.

Accessed 04/14/14.

Quist says that lionfish are going to become caught regardless of if fishermen are going after them. More will be known about how many lionfish are in the Keys and if they do well as a market fish after lobster season, since the fish will likely be caught in the lobster traps. NOAA has launched an “Eat Lionfish” campaign to try to help with the amount of fish invading the reefs. Lobster fishermen are already catching lionfish as bycatch and have found it profitable to sell them to fish houses, especially in South Carolina.