INTRODUCTION

The species *Pterios volitans* and *Pterios Miles*, commonly known as the lionfish, is a species that was introduced to the Atlantic and Caribbean Ocean from the lionfish’s native ecosystem, the Indian Ocean. The lionfish was introduced into the unnatural ecosystems through human activities, possibly from a damaged beachside aquarium during hurricane Andrew in 1992 (Williams, 2010, p.1) or could have been released purposefully by a local aquarium (Akins and Green, 2012, webinar). Thus, the lionfish is known an invasive species, which is a species that has been transported into another region that it did not belong to previously (Hare and Whitefield, 2003, p.iv). The removal of the lionfish from the non-native ecosystems has become a global controversy that bears different solutions for removing the invasive species. The human solution that has grown popular in the Caribbean is the use of spears or vinyl nets to capture and kill the lionfish in order to establish them as food for human consumption. Even though this method has caused some reduction in the species, it is not enough to stop the fish from continuing to increase in numbers in the non-native ecosystem. Another solution is to study the eggs of the lionfish and find possible solutions to find and remove the eggs before they hatch because of the large amount of offspring lionfish can produce in a short amount of time. The research can be tedious, but could lead to a large reduction in the population if found to be effective. In addition to these two solutions that are being executed today, there is a new development that employs the tactic of teaching natural predators to eat the lionfish as a natural biocontrol that should be studied. This method can be effective by having a number of local aquatic animals killing the lionfish regularly, however, this is hard method to establish. Thus, when I learned about the problems and solutions of the lionfish through my diving expedition to Grand Cayman, I decided that the evaluation of the techniques in use would be a controversial area of topic to study, which led me to ask **to what extent are the different solutions for the removal of the invasive lionfish in the Atlantic and Caribbean oceans effectively eradicating the lionfish population?**

ARGUMENT 1:

HUMAN CONTROL PLAN

 Humans are utilizing spears and vinyl nets as tools for killing the lionfish in order to establish them in the human food chain. Governments are supporting the cause by initiating the promotion of human consumption of the lionfish (Waite, 2011, p.2) Organizations such as the National Oceanic and Atmosphere Administration (NOAA) have launched a campaign called “Eat Them to Beat Them” (Richardson, 2012, p.1). A non-profit organization called Reef Environmental Education Foundation (REEF) held a lionfish derby that collected a total of 109 lionfish in one day, and two previous derbies in the Bahamas that netted more than 2,000 lionfish (Glader, 2012). Through these practices, humans are able to create a supply and demand of the lionfish by encouraging restaurants and seafood markets to serve and sell lionfish, which could possibly make a difference in reducing the abundance of lionfish (Akins and Green, 2012, webinar). In doing so, divers are eager to kill the lionfish because they now have a financial incentive to hunt down the predators. A number of relatively successful lionfish derbies have been held through out the Caribbean to remove hundred to thousands of lionfish in one day. As mentioned, divers gather lionfish is through the use of handheld spears and vinyl nets, which come with advantages and disadvantages.

SPEARING THE LIONFISH

The most common human method of removing lionfish from the non-native ecosystem is through the use of spearing the lionfish. The spears that are used by divers are usually a pole spear, which consists of a pole, a paralyzing spear tip, and a rubber loop that when pulled back and released, causes the spear to shoot and puncture a lionfish at incredible speeds (Gilo, 2012, Appendix A). The use of spears is a dangerous task that should only be used with a clear understanding of the rules and risks involved. Regulations have required a number of criterion for divers to follow who wish to kill lionfish, including professional training, recording sightings and killings of lionfish, as well as understanding any harm that could impact the reefs if the spear or diver were to miss the lionfish (Narozanski, 2012, slide 15).

Figure 1. Spear fishing pole (Pic Gat Ku 9ft polespear, 2011)

NEGATIVE IMPACTS OF SPEARS

Spears can impact the environment in a negative way if not used properly. Operations director of REEF, Lad Akins, has “seen people shoot and miss the lionfish and spear a sea cucumber or sponge instead” (Glader, 2010, p.2). Spearing the lionfish can be effective if executed properly, but poor conduct can hurt the ecosystem instead of helping. Spearing lionfish provides humans a way to reduce the number of lionfish, but is not the most effective method of removing the lionfish because it is dangerous and has the potential to harm humans and the surrounding ecosystem.

Another downside of the use of spears to kill the lionfish is that other animals are associating humans with killing the lionfish and feeding them as a free meal. Through the use of spears to feed lionfish to other fish, humans are discouraging animals to become natural predators on their own, causing any chance of other animals to help with the cause to significantly decrease. Fish that could potentially be a natural predator for the lionfish follow dive masters that have the speared lionfish with them and wait for the diver to release the dead animal into the ocean. In doing so, divers are using their license to spear the lionfish improperly, causing a major set back on improving the ecosystem.

ADVANTAGES OF VINYL NET

The other technique for trapping and killing lionfish is with the use of a vinyl net, which is a clear bag with a mesh bottom, where one does not kill the lionfish underwater, but rather captures the lionfish and kills it on shore. The use of vinyl nets is a safe method for the surrounding reefs and is easier for capturing juvenile lionfish. (Foster, 2012, Appendix A) The use of vinyl nets has to be used with caution, where a diver should position a net behind the lionfish, and then use another net to push the lionfish into the first net (NOAA, 2012). As seen in Figure 2, divers can collect a number of lionfish on a single dive, whereas using a spear does not allow for a person to hold on to a number of lionfish.

Figure 2: Diver capturing lionfish with vinyl net (NOAA, 2012)

DISADVANTAGES OF VINYL NETS

Vinyl nets require a diver to kill the lionfish with their hands, causing the diver to be susceptible to the thirteen venomous spines of the lionfish. Even though divers can wear puncture resistant gloves (Akins and Green, 2012, webinar), “the spines possess venom that is encased in an integumentary sheath or skin and contains two glandular interlateral grooves that extend three quarters the length of the spine from its base” (Halstead et al, 1955, quoted in Randall and Schram, 2011, p.4). The apocrine-type venom glands are in the thirteen dorsal spines, three anal spines, and two pelvic spines. (Morris et al, 2009, quoted in Randall and Schram, 2011, p.4). The spines are used as the primary defense mechanism for lionfish against predators and when the spine punctures the tissue, the sheath moves down the spine, compressing the venom glands (Gallagher, 2001, quoted in Hare and Whitefield, 2003, p.5). Even though human contact with the spines will not kill a person, it will cause swelling and extreme pain for the person, as well as the occasional stomach complications (Akins and Green, 2012, webinar). The stomach complications are due to having a severe allergic reaction towards to spines, and can also cause nausea, dizziness, muscle weakness, shortness of breath, headaches, and the occasional blistering of the wound area (Fatherree, 2008).

Figure 3: Lionfish’s venomous dorsal, anal, and pelvic spines (Bervoets, 2009)

COUNTER ARGUMENT 1:

REPRODUCTION RATE TOO EXTREME FOR HUMAN IMPACT

The public opinion of the Affected regions agree that spear fishing and vinyl nets are not an effective method of removing lionfish because of the exponential reproduction rate of the lionfish. Female lionfish spawn year round, every four days, and produce 25,000 eggs per batch or spawning (Richardson, 2010, p.1). Through the fishing derbies, humans have been unable to come close to the spawning rates of the lionfish. The population of lionfish is growing exponentially, and the human techniques for removing the lionfish are only killing the animal at a low and steady rate, meaning that there is no way for humans to truly make an impact on reducing the number of lionfish through their operations. Another concern with human impact is the limitations of scuba diving and the depths at which lionfish can swim. Recreational scuba divers can only dive in depths between 0-30 meters and are only affecting the ecosystem in those limits, while humans are unable to do anything about the lionfish located in depths that are beyond the diving regulations (Narozanski, Appendix F).

BUT WITHOUT THE HELP FROM HUMANS, WHAT HAPPENS?

 If humans did not step in and attempt to control the problem, then the lionfish epidemic would be a lot worse than it is today. For the present time, the human methods of spearing and vinyl nets are the quickest method known and with more time, can be proven to possibly be more effective (Akins and Green, 2012, webinar). “But with no action from humans, the lionfish population will continue to grow along the southeast United States shelf, the effects on the marine ecosystem will become more noticeable, and there will be more incidents of lionfish envenomations of divers and/or fishers” (Hare and Whitefield, 2003, p.8). Also, indirect impacts of lionfish, such as alterations of the community structure, could cause damage to the reef fish communities, especially in the coral reef environments that are already heavily stressed (Morris and Whitfield, 2009, p.17). Even though human interaction has not created a significant difference in the reduction of lionfish in the ecosystem, the action of trying to kill the lionfish is a method that is better than doing nothing.

Figure 4: Potential range of lionfish with lethal thermal minimum of 10°C (Morris and Whitfield 2009)

ARGUMENT 2:

RESEARCH SPAWNING EGGS OF LIONFISH

 An initiative that humans could potentially undergo in preventing the spread of lionfish in order to improve the ecosystem is conducting research on the spawning eggs of lionfish. “The morphological and histological structure of the scorpaeniform ovary is poorly understood, and has led to a lack of understanding of the lionfish’s reproductive evolution” (Wourms, 1991, quoted in Morris, Sullivan, and Govoni, 2011, p.2). Without the knowledge of the eggs, mature female lionfish will continue to produce up to two million eggs per year (Richardson, 2010, p.1). In the Caribbean and Atlantic Ocean, the pelagic larval duration has become sufficient enough to allow for the rapid establishment and wide geographic range of lionfish (Ahrenholz and Morris, 2009). Lionfish have an extensive reproduction rate that if inhibited, could allow for the lionfish to stop reproducing at an exponential rate. The possibility for researching the lionfish eggs could lead to a dramatic halt in the population of the lionfish. However, the tedious research that would be required is a task that is time consuming and could potentially lead to a dead end.

PROPERTIES OF LIONFISH EGGS

 When lionfish reproduce, they excrete two buoyant egg balls into the ocean as frequent as every four days (Akins and Green, 2012, webinar). Due to the buoyancy of the eggs, the eggs are can drift far away from where they were produced, causing the lionfish to be able to spread across the Caribbean and Atlantic quickly. A major characteristic of the spawning eggs that makes it difficult for researchers to research lionfish eggs is the fact that the spawning eggs are transparent (Akins and Green, 2012, webinar). Without being able to find the eggs in the ocean due to them being clear and floating, humans are not able to detect the presence of the eggs. Also, animals in the oceans are not eating the eggs because it is believed that the eggs have a protective quality of some chemical in the gelatinous matrix that inhibits the egg from being appealing to other fish (Akins and Green, 2012, webinar). Due to the eggs being undetectable and transparent, neither predators nor humans can find the eggs of the lionfish in the ocean.

THE RESEARCH THAT HAS BEEN CONDUCTED

Although research on lionfish eggs is minimal, NOAA Aquatic Invasive Species Program and the NOAA National Centers for Coastal Ocean Science have funded some research on lionfish ovaries (Morris, Sullivan, and Govoni, 2011, p.7), but no research can be conducted on the eggs because humans have found not feasible solution for collecting or tracking them. The research involved finding female lionfish throughout the shores of North Carolina to study the oogenesis and spawn formation of the offspring. The researchers would spear or use vinyl nets to collect a total sample of 718 lionfish, where they would sedate the lionfish and immediately extract the ovaries (Morris, Sullivan, and Govoni 2011, p.2). With the ovaries, the researchers discovered and named the different stages in which the lionfish eggs are made.



Figure 5: Lionfish ovary with unreleased gelatinous egg mass. GE = gelatinous egg mass; OT = ovigerous tissue. (Morris, Sullivan, and Govoni, 2011, p.6)

The first stage, called the primary growth stage, involves the ovaries containing a prominent germinal vesicle, visible chromatin, and single or several basophilic nucleoli (Morris, Sullivan, and Govoni, 2011, p.3). In contrast, the last stage of the ovaries, known as the maturation stage and ovulation, is where the diameter increases significantly, there is a migration of the germinal vesicle, and a gelatinous matrix surrounds the new batch of ova (Morris, Sullivan, and Govoni, 2011, p5-6). Once the ovaries have undergone maturation, spawn formation occurs. Spawn formation is the idea that the gelatinous egg masses pass into the gonoduct, leaving an opening at the end of the gelatinous egg mass, and is released during spawning (Morris, Sullivan, and Govoni, 2011, p.6). The information gathered from the research shows that studying the ovaries of the lionfish allows for humans to begin understanding the eggs and reproduction of the lionfish. Even though this research is just a start, it demonstrates a promising and possibly successful area of research in removing the lionfish through the spawning eggs. Due to the greater understanding of the different cycles and process’s of the spawning eggs, researchers can possibly develop a technique or chemical that can inhibit the production of the lionfish and drastically restore the ecosystems back to their original state.

COUNTER ARGUMENT 2:

TEDIOUS RESEARCH IS TIME CONSUMING WITH A POTENTIAL DEAD END

 Although the little research that was conducted provided a large amount of information on the eggs, the time that it took to gather the research with only three researchers at work caused the task to take a long time to gain results. The sample size of lionfish collected was 718 female lionfish, which was a tedious task for the researchers to gather with the use of vinyl nets or spears, as well as making sure that the lionfish were not killed (Morris, Sullivan, and Govoni, 2011, p.2). In doing so, the time to capture the female lionfish as well as their eggs in the ocean is a task that may not be accomplished with a conclusion in the near future.

Currently, researchers are unable to find the buoyant eggs of lionfish in the natural ocean due to its transparent quality. Due to the fact that lionfish are found in a variety of habitats and in very deep waters, it would be extremely difficult to remove eggs of all lionfish (Skylar, Appendix D). If the eggs are never found, then the research for the eggs will continue to be minimal and lead to no avail. If researchers were to pursue their search for the invisible eggs or pregnant female lionfish, then protecting the ecosystem is put on hold.

ARGUMENT 3: NATURAL PREDATOR AS A BIOCONTROL

 The theory that a predator should be found for the lionfish to remove them from the ecosystem is a concept that is becoming popular within divers as well as bringing an abundant amount of successful outcomes. The most popular marine animals that have begun to consume the lionfish are groupers, reef sharks, and moray eels. But in order for a predator to truly become a biocontrol, the predator effects would have to require a significant new impact on the density of the prey (Mumby, 2011, p.1). The possibility of a marine animal actively hunting the lionfish will take patience and practice by divers, but can eradicate the lionfish in little time.

The advantage of having a natural predator fight the invasion is the idea that there are a large number of the potential predators, as well as predators being in the water and hunting the lionfish twenty four hours a day, seven days a week. Humans can only dive for around an hour at a time, at a max of 4-6 times a day. The other factor that limits divers is the regulated due to scuba depth limitations and scarcity and cost of human resources; Divers can’t possibly cover the entirety of lionfish habitat in the region (Akins L. Waterman S. 2012, p.21). Lionfish have been found in marine habitats from inches-deep to more than 1,000 feet and, which is too much ground for humans to possibly cover (Akins L. Waterman S. p.21).

THE STEPS TAKEN BY DIVERS ALREADY

 In my trip to the Cayman Islands, dive masters that would spear the lionfish and not have a net to put the lionfish in would usually try to find a nearby fish that was in search of a free meal. Divers would feed the half-dead carcasses to groupers, and on one particular dive, a lobster consumed a lionfish (Gilo, 2012, Appendix A). Not only do divers feed the lionfish to aquatic animals, but researchers have now begun to conduct experiments to determine if the idea of a natural biocontrol is even possible. Through Mumby’s research, the group found that the grouper would be able constrain the invasion over a 3 year period, which provides insight to the feasibility of natural biocontrol (Mumby, 2011, p.2). Photographer Antonio Busiello was able to capture the iconic moment of a reef shark eating a lionfish, which brings a spark of hope of the new way for battling the lionfish (Choi, 2011, p.1). If scuba divers were to continue training the different marine life to eat the lionfish, then hopefully one day the predators will actually search for the food on there own without assistance from humans.

Figure 6: Reef shark eating lionfish in the open ocean above coral reef (Busiello, 2011)

COUNTER ARGUMENT 3:

TOO LATE TO TEACH A PREDATOR TO HUNT LIONFISH

 Humans that use spears and vinyl nets to remove the lionfish personally will sometimes kill a lionfish and then feed the carcass to a fish that has observed the attack, usually a grouper or another large fish. When humans do this, they are teaching the potential predators to not have to hunt down lionfish, but are given a free meal. Although humans now know that other animals can eat the lionfish without any noticeable harm to them, they are not associating the predators to kill live lionfish on there own. Dive professional Sergio Tritto began spearing the lionfish for weeks and conducted shark-feeding dives (Akins L. Waterman S., 2012, p.19). When Tritto realized that the sharks might just be interested in his kills, he experimented with killing the lionfish by releasing a wounded lionfish into the open water, where a shark quickly gobbled up the lionfish (Akins L. Waterman S., 2012, p.19). Even though Tritto observed the reaction of a human killing the lionfish means a free meal to a potential predator, the concept of a marine animal actually searching for the lionfish is not taken into account. Lionfish live in holes along the reefs and do not come out into the open waters very often. If another marine animal is to actually eat the lionfish on its own, then they need to be taught to search for lionfish within the reefs and not within the open oceans. Due to the actions humans have been taking, finding a natural predator to hunt the lionfish in the holes of reefs might be an action that is too late to teach.

PREDATOR LIMITATIONS

A final factor that might cause a halt in the establishment of a predator is the idea that the marine life being taught right now does not swim long distances. For example, the reef shark is a non-pelagic shark, meaning that the stick within the few miles that make up their reefs and don’t travel far (Choi, 2011, p.2). But the complication of the predators actually searching within the rock holes and cracks in the coral on their own caused a dilemma in what future outcomes would occur with a natural predator (Foster, 2012, Appendix A). The size of a lionfish is much smaller than the size of a reef shark or grouper, causing the lionfish to be able to easily protect itself from the predators if they were to be eventually threatened.

CONCLUSION:

 Whether the lionfish was introduced to the ocean by a damaged aquarium during a hurricane, or by an aquarium operator purposefully releasing the lionfish into the ocean, the dilemma of eradicating the intrusive lionfish falls to the hands of humans. Due to the controversial dilemma that was created, the focus of my paper was about **to what extent are the different solutions for the removal of the invasive lionfish in the Atlantic and Caribbean oceans effectively eradicated the lionfish population?** Due to the fact that lionfish were introduced by human activity, then humans have an obligation to clean up the mess that they made. Whether or not humans spear the fish, research the lionfish eggs, or create a natural predator, more information needs to be researched and evaluated about the situation in order to truly determine the path that will eradicate the lionfish from the non-native ecosystem. Through the research that has been conducted, the path of training a natural predator to be a biocontrol for the lionfish seems to be the most successful plan for removing the invasive lionfish. A natural predator contains a larger population than humans, has contact with lionfish more frequently, and can dive deeper depths than humans. Even though human efforts of spearing and netting the lionfish and researching the eggs have come to some avail, the idea of training predators to kill lionfish should be the way that divers expend their time and energy into eradicating the lionfish and improving the marine ecosystem in the Atlantic and Caribbean Oceans.

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APPENDICES

Appendix A

Cayman Islands Journal Entry

March 31st, 2012

Today was the first day that I was able to dive on my own as an official licensed scuba diver! Scuba diving master Josh Fosters and Evytar Gilo took us to the west side of the Island to “Little Tunnel” and “Arm Chair” dive spots. On this boat, a group of 4 scuba divers had spears and vinyl nets in order to capture lionfish. As we got around to talking to the group, the group of divers as well as Josh and Evy began to explain the problem at hand. Lionfish are consuming thousands of little fish species, producing large amounts of eggs in such a short time, and humans are now killing them and selling them to the local restaurants and markets. Evy then showed me the mechanics of the spears, where there is a paralyzing spear tip, a rubber loop that is pulled back and releases the spear to puncture the lionfish at incredible speeds. Unfortunately, Evy would not let me take the spear on my dive because I was not an experienced scuba diver. However, another part of the lionfish experience caught my eye. I noticed that one of the lionfish divers did not carry around a spear, but rather a mesh net. Upon asking Fosters why he had no spear and just a net, he explained that the nets were a safer method for capturing lionfish in the surrounding reef, as well as easier for capturing the juvenile lionfish that can not be simply speared. The excitement of the lionfish hunt only made me want to dive in the water and stab one for myself.

 On the actual dives, we were told that we would find a number of lobsters, which was a very shocking fact to me because I always thought that they were a nocturnal creature. In my thrill of seeing large lobsters along the coral, scuba diving master, as well as the trained divers, searched for lionfish in small caves in the reef, as well as on the tops of the coral reef. On the dive, Evy speared and killed a lionfish and was wondering the corals with the lionfish. Then Evy found a lobster that was protruding from the coral, and release the lionfish right in front of the lobster’s face. I was baffled by the idea that in a split of a second, the lobster grabbed the fish and swam into the cave without leaving a single trace behind.

 Once all the divers were back on the boat, the lobster eating the lionfish was the hot topic on deck. People could not believe that the lobster, of all creatures, would come to eat a lionfish. Due to the “rebel lobster,” as divers were calling the lobster, the discussion of a potential predator for the lionfish quickly flowed its way into the conversation. But the complication of the predators actually searching within the rock holes and cracks in the coral on their own caused a dilemma in what future outcomes would occur with a natural predator. The discussion was very enthusiastic and debatable, but created a great story that could be told to other divers. The dives today were very informational but also caused me to view the ocean in a different light, where I realized that there is a big threat towards the reef ecosystem, and made me want to take action!

Appendix B

From: jculman@comcast.net

Sent: Monday, April 23, 2012 5:27 PM

To: janna@reef.org

Subject: Research Paper

Ms. Janna Nichols

My name is Justin Culman and I am from the George Washington High School International Baccalaureate Program. I am writing a research paper called an Extended Essay that will be about 20 pages long on the invasion of lionfish in the Caribbean. I have selected this topic due to my recent interest in scuba diving and a personal experience of the controversy when I visited Grand Cayman. I understand that your organization is conducting research on the invasion of lionfish and would value your research for my paper. I would like for any hands-on opportunities that you could provide. I have obtained my scuba diving certification and would be interested in possibly utilizing this to observe the problem with the use of your program. Please let me know if you are able to help me with my research in any way and I appreciate and value your time for helping out a student interested in this science topic.

Thank you for your time,

Justin Culman

From: janna@reef.org

Sent: April 23, 2012 6:35:29 PM

To: jculman@comcast.net

Subject: RE: Research Paper

Cc: Lad@reef.org, martha@reef.org

Justin,

Thanks for contacting REEF about your research project. Talk about good timing on your part -  I have something that might be of use to you! This Wednesday evening, at 8pm Eastern time, Lad Akins will be presenting a Lionfish online webinar for REEF. We'd invite you to join in. You'll be able to interact and ask questions as well as maybe get some good information. You can sign up for it here:

<http://www.reef.org/resources/webinars>

Lad will also be able to direct you further about other ideas, and I am copying him on this email.

- Janna

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Janna Nichols

REEF Outreach Coordinator

[www.REEF.org](http://www.REEF.org/)

360-798-6414

Underwater Photography

Pacific NW Scuba

www.pnwscuba.com

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Appendix C

From: jculman@comcast.net

Sent: May 07, 2012 12:22 PM

To: allene@ispearlionfish.org

Subject: Research Paper

Mr. Allene,

My name is Justin Culman and I am from the George Washington High School International Baccalaureate Program. I am writing a research paper called and Extended Essay that will be about 20 pages long on the invasion of lionfish in the Caribbean. I have selected this topic due to my recent interest in scuba diving and personal experience of the controversy when I visited Grand Cayman. I understand that your organization is spearing the invasive lionfish and would like to ask if you have any opportunities for me to observe the spearing hands-on. I have obtained my scuba certification and would be interested in possibly utilizing this to observe the problem with the use of your program. Please let me know if you are able to assist me with my research in any way and I appreciate and value your time for helping me out as a student interested in this science topic.

Thank you for your time,

Justin Culman

From: allene@ispearlionfish.org

Sent: June 1, 2012 2:55:40 PM

To: jculman@comcast.net

Subject: Re: Research Paper

Hi Justin ... I'm so sorry to be this late in answering. My laptop completely died and I've spent the last three weeks getting a new one, trying to retrieve all my old information, saved websites, passwords, etc. Today is the first time I've checked my ISL mail in a month! I hope this is not too late for you. You can come to Bocas any time you want and I'll make sure you get to dive for lionfish. I have friends that go nearly every day. Let me know if you are making any plans to get here. If you need info on best ways to get from Panama City to Bocas, or from San Jose, Costa Rica to Bocas, let me know.

Again, sorry so late!

Allene

Appendix D

From: jculman@comcast.net

Sent: May 8, 2012 6:50:15 PM

To: skylarmiller@ceibahamas.org

Subject: Research Paper

Skylar Miller,

My name is Justin Culman and I am from the George Washington High School International Baccalaureate Program in Denver, Colorado. I am writing a research paper called an Extended Essay that will be about 20 pages long on the effectiveness of the different techniques to remove the invasive lionfish from the Caribbean and Atlantic Ocean. I have selected this topic due to my recent interest in scuba diving and a personal experience of the controversy when I visited Grand Cayman. I found your institute while researching the topic and would value your research for my paper. I would like to know if you have any hands-on opportunities that could allow me to observe the problem with my own eyes. I have obtained my scuba diving license and would be interested in possibly utilizing this to observe the problem with your help. Please let me know if you are able to help me with my research in any way and I appreciate and value your time for helping a student interested in this science topic.

Thank you for your time,

Justin Culman

From: skylarmiller@ceibahamas.org

Sent: May 21, 2012 6:22:41 PM

To: jculman@comcast.net

Subject: Re: Research Paper

Cc: Lad Akins <lad@reef.org>, Stephanie Green <stephanie.green@sfu.ca>, Annabelle Oronti <annabellebrooks@ceibahamas.org>, Karen Knight <karenknight@islandschool.org>

Hi Justin,

Thank you for your interest in our Lionfish Program at CEI.  It sounds like you're taking on an exciting project and it is indeed a great idea to get hand's on experience in your topic.  Unfortunately, we are at capacity with our summer interns! Also, we require that interns are at least high school graduates (over 18).  I would recommend looking into the Earthwatch program  <http://www.earthwatch.org/aboutus/>  which holds a course at CEI this July. Much of their work will be focused on the same coral reef ecosystems that we study under our Lionfish research program. I would also encourage you to check out our GAP year program if you are interested in pursuing more hand's on experiences post high school before college.  <http://ceibahamas.org/gap-year.aspx>

Please let me know if you have any more questions and best of luck with your project!

Skylar

From: jculman@comcast.net

Sent: May 22, 2012 4:24 PM

To: skylarmiller@ceibahamas.org

Subject: Re: Research Paper

Skylar,

Thank you for the information on where I can find programs that are looking into the issue. I also wanted to ask if I could email you some questions about your research and your thoughts about the issue. Please let me know if you have the time to answer questions because I know that you have a busy schedule and want to make sure you would be ok with taking time to answer the questions.

Thank you,

Justin Culman

From: skylarmiller@ceibahamas.org

Sent: May 23, 2012 7:58

To: jculman@comcast.net

Subject: Re: Research Paper

Hi Justin, I’m happy to answer you questions, if I can! Send them along and I’ll do my best to get back to you.

Cheers,

Skylar

From: jculman@comcast.net

Sent: May 23, 2012 9:02 PM

To: skylarmiller@ceibahamas.org

Subject: Re: Research Paper

Here is a list of questions that I would appreciate you answering:

What research do you conduct and where do you conduct that research?

Do you think that using spears or vinyl nets to kill lionfish and establishing them in the human food chain is an effective method for significantly reducing the number of lionfish? Why or why not?

What are your thoughts on trying to research the eggs of lionfish in order to potentially remove them?

Thank you,

Justin Culman

From: skylarmiller@ceibahamas.org

Sent: May 24, 2012 8:00:09

To: jculman@comcast.net

Subject: Re: Research Paper

See my responses below in red. Hope this helps!

What research do you conduct and where do you conduct that research? Our research at the Cape Eleuthera Institute focuses on assessing the impacts that invasion lionfish have on the native reef fish community.  We conduct monthly surveys on reefs to monitor changes in lionfish and native fish densities.  Our research is carried out on a number of patch reefs in south Eleuthera, The Bahamas.

Do you think that using spears or vinyl nets to kill lion fish and establishing them in the human food chain is an effective method for significantly reducing the number of lionfish? Why or why not? Unfortunately, lionfish do not have any known natural predators in their invaded range (western Atlantic and Caribbean).  It is possible that given enough time, something will begin controlling lionfish populations naturally.  However, many species are naive at this point and it is therefore up to humans to help control this invasive species.  Local removal of lionfish by spear or nets has been effective in reducing lionfish numbers in specific areas.  I think that promoting lionfish as a food/ fishery can lead to successful control.  At the Cape Eleuthera Institute, we encourage local fisherman to harvest lionfish and local restaurants are beginning to become interested in serving lionfish on their menus.

What are your thoughts on trying to research the eggs of lionfish in order to potentially remove them? Do you think this method would be effective?  Very little is understood regarding lionfish reproduction.  This is an area that needs to be studied more. I am not sure exactly what you mean by removing eggs.  Lionfish are found in a variety of habitats and in very deep water, so it would be extremely difficult to remove eggs of all lionfish - just as it will be impossible to eradicate all lionfish.

From: jculman@comcast.net

Sent: May 24, 2012 2:35 PM

To: skylarmiller@ceibahamas.org

Subject: Re: Research Paper

Skylar,

Your responses are greatly appreciated!

Thank you,

Justin Culman

Appendix E

From: jculman@comcast.net

Sent: May 16, 2012 4:55 PM

To: alicel.driver@gmail.com

Subject: Research Opportunities

Alice Driver,

My name is Justin Culman and I am from the George Washington High School International Baccalaureate Program in Denver, Colorado. I am writing a research paper called an Extended Essay that will be about 20 pages long on the effectiveness of the different techniques to remove the invasive lionfish from the Caribbean and Atlantic Ocean. I have selected this topic due to my recent interest in scuba diving and a personal experience of the controversy when I visited Grand Cayman. I found your contact while reading your article online while researching the topic and would value your research for my paper. I would like to know if you have any fieldwork opportunities that could allow me to observe the problem with my own eyes or any information that you can give me that could help me with my paper. I have obtained my scuba diving license and would be interested in possibly utilizing this to observe the problem with your help. Please let me know if you are able to help me with my research in any way and I appreciate and value your time for helping a student interested in this science topic.

Thank you for your time,

Justin Culman

From: alicel.driver@gmail.com

Sent: May 16, 2012, at 8:42 PM

To: jculman@comcast.net

Subject: Re: Research Opportunities

Hi Justin,

I would get in touch with Andrzej Narozanski at andrzej@utilaecology.org to discuss opportunities to study lionfish. He is in charge of the research on Utila, Honduras and is a great resource. I will send you a presentation he gave via Dropbox that has a lot of great information about lionfish.  Everything I learned, I learned from him. If you have any more questions, just let me know.

Best,

Alice

From: jculman@comcast.net

Sent: May 18, 2012, at 2:45:15 PM

To: alicel.driver@gmail.com

Subject: Re: Research Opportunities

Alice,

Thank you so much for the reference and the presentation. It is very helpful with my research.

Thank you,

Justin Culman

Appendix F

From: jculman@comcast.com

Sent: May 21, 2012, at 2:05:09 PM

To: andrzej@utilaecology.org

Subject: Lionfish Research

Mr. Andrzej Narozanski,

My name is Justin Culman and I am from the George Washington High School International Baccalaureate Program in Denver, Colorado. I am writing a research paper called an Extended Essay that will be about 20 pages long on the effectiveness of the different techniques to remove the invasive lion fish from the Caribbean and Atlantic Ocean. I have selected this topic due to my recent interest in scuba diving and a personal experience of the controversy when I visited Grand Cayman. I found your contact through Alice Driver and would value an interview over email or the phone for my paper. Please let me know if you are able to help me with my research in any way and I appreciate and value your time for helping a student interested in this science topic.

Thank you for your time,

Justin Culman

From: andrzej@utilaecology.org

Sent: May 22, 2012, at 3:45 PM

To: jculman@comcast.net

Subject: Re: Lionfish Research

Hi Justin,

Many thanks for the email. I have no problem with taking part in an

interview for your research on lionfish. If you could send me through a bit

more information on your course/institution (just really to introduce where

you are from) and a list of questions then I will be able to get them to you

as soon as can.

Best regards,

Andrzej Narozanski MSc

Bay Islands Project Coordinator

Centre for Marine Ecology

Roatan, Bay Islands, Honduras

[www.utilaecology.org](http://www.utilaecology.org/)

From: jculman@comcast.net

Sent: May 23, 2012 2:54:10 PM

To andrzej@utilaecology.org

Subject: Re: Lionfish Research

Andrzej,

The course that I am enrolled in is the International Baccalaureate Program at a Public High school in Denver, CO. In this course, we study different areas of knowledge at a college level, and in my case, I am studying biology, psychology, English, calculus, Spanish, philosophy, and in the next year will be studying environmental systems. In order to pass the program, we are required to write a research paper that is similar to a college thesis at the end of our junior year. We have the freedom to choose any area of knowledge for our paper and can discuss any topic that we wish to study. I know that marine biology is a course that I will pursue in college and choose it as my research paper in order to get a head start in the area. In March, I was able to visit Grand Cayman and ask divers and professionals about the problem, which is an element that my course highly encourages. Our paper is completely independent, except for having help from an advisor, and the paper must relate to a course work that we are studying, in my case it is biology. I hope this is information that helps you understand the course that I am enrolled in, and if you have any questions about it, feel free to ask.

Here is a list of questions that I have for you:

What research do you conduct and where do you conduct that research?

Do you think that using spears or vinyl nets to kill lion fish and establishing them in the human food chain is an effective method for significantly reducing the number of lionfish? Why or why not?

What are your thoughts on trying to teach other animals to be a natural biocontrol for the lionfish? Do you think this method would be effective?

From: andrzej@utilaecology.org

Sent: May 25, 2012, at 1:43 PM

To: jculman@comcast.net

Subject: Re: Lionfish Research

Hi Justin,

Thank you for the information. I'll get back to you with some answers early

next week if that is ok.

Best,

Andrzej

From: jculman@comcast.net

Sent: May 27, 2012 5:18:45 PM

To: andrzej@utilaecology.org

Subject: Re: Lionfish Research

Andrzej,

Thank you for taking the time to answer the questions and early this week sounds great.

Thanks,

Justin Culman

From: andrzej@utilaecology.org

Sent: May 29, 2012, at 11:43 AM

To: jculman@comcast.net

Subject: Re: Lionfish Research

Hi Justin,

See attached word doc for my file. I hope my answers are of use. If you have

any other questions or want more info on anything specific feel free to send

it over. Good luck with then final product!

All the best

Andrzej

Attatched File:

Hi Justin,

See below for my responses.

Brief Introduction

I am the Bay Islands Project Coordinator for the Centre for Marine Ecology, Honduras. Our main office is located in Tegucigalpa (the capital), however I am lucky enough to be located on the island of Roatan. I have been in the Bay Islands since March 2009 and therefore have been around before, during and after lionfish made it to the islands (Roatan – May 2009 and Utila – July 2009). I used to run the lionfish programme on Utila for my organisation and have been involved in all aspects of the invasion, research, community outreach and managing control programmes.

What research do you conduct and where do you conduct that research?
Most recently my research has been based around compiling information on all things to do with lionfish in the Bay Islands, Honduras for the production of a Bay Islands Lionfish Management Plan, which is part of the Bay Islands National Marine Park Management Plan for the Honduran Government. For the management plan I needed to compile information on the following topics

1. Background (desk research based on research journals, reports etc)
	1. Species Description – Genetics and Taxonomy
	2. Lionfish Reproductive Biology
	3. Lionfish Feeding Ecology
	4. Defence and Venomology
	5. Health Risk for Marine Users
	6. Distribution and Invasion History (Native Range & Invaded Range)
	7. Ecological Threats (Regional and in The Bay Islands)
	8. Economic Threats (Regional and in The Bay Islands)
2. Revision of Existing Management Activities
	1. The History of Invasion in Honduras and the current situation
	2. Honduran lionfish legislation (list and integrate analysis)
	3. Description of activities on Utila / Roatan / Guanaja
	4. Limitations of current activities

Part of point 2a. was to provide information on data on sightings and captures from marine users primarily divers since their arrival in 2009. This information was collected from the two organisations that coordinate the lionfish programmes on Utila (Centre for Marine Ecology) and Roatan (Roatan Marine Park), which gave us an indication on the distribution and numbers of lionfish around the islands, which would help us in targeting specific areas were the removal of lionfish could be focused. This information however is not considered fully “scientific” and therefore there is the need to document their density and distribution using scientific survey methods to increase the accuracy of our knowledge. I am currently assisting a student who is carrying out a lionfish density study within the boarders of Roatan Marine Park (where control using licensed Hawaiian slings exerts a high fishing pressure and therefore removal) compared to outside the marine park (where fishing pressure is low).

Other aspects of my research include developing a lionfish fishery to provide a short-term alternative to catching fish / seafood items that are already over exploited in the Bay Islands such as grouper, conch and lobster. Through the development of this fishery, as lionfish are being promoted as a sustainable and delicious seafood option it will also help to reduce their numbers on the reef through targeted intensive fishing while allowing the fisheries (mentioned previously) to hopefully recover.

Do you think that using spears or vinyl nets to kill lionfish and establishing them in the human food chain is an effective method for significantly reducing the number of lionfish? Why or why not?

I believe that promoting them as a food source is an effective way of reducing their numbers, however this is only really successful in water depths between 0-30m due to the limitations of scuba diving and skin diving. Below these depths were divers don’t often go we cant really do much at the moment to control them. Therefore we will only be able to control their numbers in a relatively small proportion (in the grand scale of things) of our reefs. But I do think something is better than nothing, and as lionfish appear to be here to stay then I think currently this is best we humans can do.

If you look at how fish populations in general across the globe have been devastated, it is by over fishing due to a high demand from consumers. Therefore the theory goes that if you want to dramatically reduce a population of fish then you simply tell humans that it is tasty and they can eat it. This may sound cynical however unfortunately it is true.

Another project that I have developed is the Bay Islands Responsible Seafood Guide <http://www.facebook.com/pages/The-Bay-Islands-Responsible-Seafood-Guide/240190615992031> which promotes lionfish as a sustainable seafood choice in the region, so this is something I think is a good idea. The important thing however is we have no idea how sustainable or effective this type of activity will be over time, and really only time will tell.

What are your thoughts on trying to teach other animals to be a natural biocontrol for the lionfish? Do you think this method would be effective?

As part of the lionfish programme I coordinated on Utila, we had numerous reports on regular basis of divers spearing lionfish, presenting them to native fish species and observing them being eaten. At first we were hesitant to encourage this as we had no idea of how native fish (such as grouper, snapper, moray eels, triggerfish and sharks) would react, particularly if they got stung by one of the lionfish’s venomous spines. Our concerns for the most part were put to rest on this matter, as you would see the same resident fish eating lionfish over and over again. So as far as we could see there was no detrimental effect of the lionfish venom or sharp spines on the fish that were eating them. I would still like to see some research done to back this up, so we know for sure that the fish eaten them aren’t being affected.

From a safety point of view, in my experience we did observe that some of the resident fish whom would frequently eat speared lionfish would follow divers in the hope that they would get an easy meal. This sort of close interaction is nice, but ultimately they are wild animals and perhaps our contact with them should just be confined to watching them underwater rather than actively feeding them. I mention this because they are wild animals and getting close to them and interacting with them in this way could increase the risk of injury to divers.

Biocontrol could to be our greatest weapon in reducing lionfish numbers, as native predators can reach depths and parts of the reef that we cannot. Perhaps the best thing to do is let them work it out for themselves and by doing this we reduce the risk to divers. There are definitely pros and cons to teaching native fish to eat lionfish. Teaching native fish to eat lionfish off spears gives them a taste for the fish, but only really teaches them to eat dead or injured fish that divers have caught. I have only heard of one incidence of a queen triggerfish actively hunting and eating a live lionfish. However this triggerfish was in an area where a lot of spearing of lionfish takes place. So does this mean that being feed lionfish by spears before has caused this fish to go and hunt lionfish on its own? Well we can’t say for sure but it is a convenient coincidence, so it therefore could be a positive thing.

The other issue if we don’t try and teach them is that it could take decades for them to work it out themselves. An example I like to use when teaching people about why we are spearing them, is the cane toad…they were introduced in Australia about 80 years ago to reduce pests that were destroying sugar cane crops. The cane toad however is poisonous and couldn’t be eaten by native predators. 80 years later numerous native predators have now either worked out how to eat them without being poisoned or have evolved resistance to the cane toad poison. Basically it could take decades for the native fish to realize lionfish as a prey item, but again we just don’t know. So perhaps a little push in the right direction by teaching a few and hope that it is passed on through the population is a good idea. The debate is open on this one!

From: jculman@comcast.net

Sent: June 10, 2012, 9:07:04 PM

To: andrzej@utilaecology.org

Subject: Re: Lionfish Research

Andrzej,

Your responses to the questions were more than I could of asked for. Thank you so much for taking the time to answer the questions and putting in a lot of depth into the responses.

Thank you again,

Justin Culman

Appendix G

From: jculman@comcast.net

Sent: April 23, 2012 6:23:24 PM

To: Christy@reef.org

Subject: Research Paper

Ms. Christy Pattengill-Semmens

My name is Justin Culman and I am from the George Washington High School International Baccalaureate Program. I am writing a research paper called an Extended Essay that will be about 20 pages long on the invasion of lionfish in the Caribbean. I have selected this topic due to my recent interest in scuba diving and a personal experience of the controversy when i visited Grand Cayman. I understand that your organization is conducting research on the invasion of lionfish and would value your research for my paper. I would like for any hands-on opportunities that you could provide. I have obtained my scuba diving certification and would be interested in possibly utilizing this to observe the problem first with the use of your program. Please let me know if you are able to help me with my research in any way and I appreciate and value your time for helping out a student interested in the science topic.

Thank you for your time,

Justin Culman

Response: None

Appendix H

From: jculman@comcast.net

Sent: May 8, 2012 6:37:32 PM

To: reefhq@reef.org

Subject: Research Paper

Mr. Lad Akins,

My name is Justin Culman and I am from the George Washington High School International Baccalaureate Program. I am writing a research paper called an Extended Essay that will be about 20 pages long on the effectiveness of different solutions on the removal of lionfish in the Caribbean and Atlantic Ocean. I have selected this topic for my paper due to my recent interest in scuba diving and a personal experience of the controversy when I visited Grand Cayman. I watched your webinar with Stephanie Green and understand that you work with REEF as well as other organizations and would value your research for my paper. I would appreciate if you could direct me to any hands-on opportunities, whether it be with your organizations or another company. I have obtained my scuba diving license and would like to utilize this in order to observe the problem with my own eyes. Please let me know if you are able to help me or redirect me to anyone and I appreciate and value your time for helping out a student interested in this science topic.

Thank you for your time,

Justin Culman

Response: None