

Spatial Narrative of the Invasive Lionfish in the Western Atlantic and Caribbean Oceans
A GIS Story Map

by

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I dedicate this work to my wife and family, without their support and patience I would have never finished this lifelong goal

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List of Abbreviations

GIS	Geographic information system
NCC	National Capital Commission
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
ONMS	Office of National Marine Sanctuaries
SME	Subject Matter Expert
USGS	United States Geological Survey

Abstract

Two subspecies of Indo-Pacific lionfish, (*Pterois volitans* and *Pterois miles* Family Scorpaenidae) are the first invasive marine fish that are spreading rapidly throughout the Western Atlantic and Caribbean waters (Schofield 2010, S117-S122). The lionfish were introduced to Florida waters in the mid 1980's; however, little is known about the lionfish population and the long-term effects this non-native carnivore will have on our native reefs. Despite increased awareness among wildlife and marine professionals, the public remains in the dark about the ever-growing lionfish populations in the on Western Atlantic reefs. Through a case study of the Story Map model this project utilizes the spatial data revealing chronological factors of the lionfish population growth and spread throughout the entire Western Atlantic. This study is designed for informing the lay citizen and inspiring them to act. The Story Map model is a public interactive web platform, or portal into the story of the lionfish. Using a Story Map, this project seeks to raise public awareness of the rising populations of lionfish in Florida coastal waters. The primary goal of this thesis is to inspire individuals through the Story Map to get involved their coastal communities. The Story Map combines interactive maps and high definition media to communicate the lionfish population growth as well as how the lionfish have affected the communities. This effective use of a Story Map is highly adaptable and the purpose can change as the focus of the invasive lionfish changes too. This Story Map model is simple, highly flexible, and can rely exclusively on public data. This thesis is a call to the public to increase awareness and involvement to aid our native Atlantic and Caribbean reefs against this invasive species.

Chapter 1 Introduction

The lionfish is as unique as a butterfly, as fierce as the most dangerous of predators, and exceedingly venomous. The lionfish is a formidable threat to Western Atlantic reefs for it is not native to the region. Lionfish are native to the Indo-Pacific region of the world but have taken hold in Western Atlantic reefs. Little is known about how the lionfish were introduced to the Western Atlantic, and the overall timeline of the lionfish invasion is poorly recorded and understood. The immediate threat and management of these invaders is now more critical than ever before. In the early 1980's, scientists were notified of a few sightings of the Indo-Pacific lionfish in waters off the coast of Miami, Florida. No one could have predicted the spread and rapid population growth that has now expanded from Rhode Island down to Brazil in a few short decades (Schofield 2009). Due to how recent this marine fish invasion happened, little is known about the long-term consequences of these foreign predators. What is urgent is the immediate need to raise awareness to inspire others to contribute to the population control of the lionfish within native Western Atlantic and Caribbean reefs. This case study was designed with informing the lay public on the environmental threat of the invasive lionfish. Furthermore, this study describes the creation of an online effort, via an Esri Story Map, to raise public awareness of the invasive lionfish.

Throughout the centuries, cultures have inspired and motivated their populations through stories. Stories, or narratives, help provide a way of understanding our place within the scheme of things. Esri provides an online tool that we can use to share the story of the lionfish and help community members find their individual role within this marine invasion narrative. The Esri Story Map conveys the narrative combined with authoritative maps, images, and multimedia that harness the power of our story to help inspire the observer to contribute in their own way.

Geography has always been important since the dawn of humanity. In the stone age where hunters anticipated the location of their prey, they relied on the geography for their sustenance. Their spatial awareness was key to whether they lived or died (Bolstad 2012). Furthermore, early explorers applied geography in forms of maps as shown in Figure1 (Bolstad 2012). Applied geography in the form of maps has served in the discovery, planning of many



Figure 1. Diego Gutierrez 1554-1569 Western Atlantic Ocean

civilizations. Upon the discovery of the Americas many early explorers used maps of the Western Atlantic to navigate the tropical waters (Gutierrez 1554).

Spatial information has a far-reaching impact on our daily lives. Recent technological advancements in mobile technology has mobile users utilizing maps as part of their everyday routine. Most often, our modern day geographic knowledge is applied to which route

has the least amount of traffic, or finding where the closest restaurant is located. True spatial awareness impacts our daily routine more than we realize. Spatial information helps produce the food we eat, the energy we burn, even information as to where the next school will be built (Bolsted 2008).

1.1. Motivation

For centuries, maps have been the primary way for people to find their destination (Bolstad 2012). Maps can also tell darker stories, such as those during times of war and turmoil. Although the purpose of a single map can change based on the individual circumstances, the steady fact remains that we are constantly affected by our geography (Bolstad 2012). The story that an individual map conveys is also unique to the user's purpose. For example, the map of the stars helped early mariners find their way across the great oceans, and the same map can help astronomers find their celestial body of study. Similarly, a good story or novel with its plot twists and well-developed characters can help us to imagine ourselves in the role of the heroine or villain, thus placing us in the novel's narrative. Combining the adventurous nature of maps and vivid narrative can transport people to places, scenes, or a unique geography. The sole purpose of this project is to combine the power of an engaging narrative with the enhanced impact of our geospatial instincts to inspire people to act. Only through our actions can our native reef populations be saved from these lionfish invaders. John F. Kennedy once said, "There are risks and costs to action. But they are far less than the long-range risks of comfortable inaction."

The Western Atlantic reefs encompass a geographically diverse area, including the Caribbean, South Florida, and the Bahamas to name a few. The only coral reefs along any U.S. main land borders are the coral reefs along the Western Atlantic coastlines (Ohlhorst 1988).

Coral reefs are adapted to stable environments that change slowly over millions of years. Coral

species that build coral reefs are called hermatypic or “hard” corals, because they can extract nutrients to build their skeletal structures from natural sea water. Coral polyps build upon each other. For example, a new polyp will live on the calcium exoskeletons of their ancestors, adding their own exoskeleton to the already existing structure (Bowen 2015). Coral reefs grow slowly. When enough time passes, they become visible to humans and over time can grow to enormous underwater structures. Coral reefs are found all over the world with the largest being on the shores of Australia, known as the Great Barrier Reef (Bowen 2015).

The irreplaceable coral reefs around the world are suffering many global changes that are well beyond the scope of this project however, it is important to mention that we, as humans, are placing these animals under many stresses. Corals are sedentary animals very complex in their anatomy. Corals enjoy a symbiotic relationship with zooxanthella, plant cells that live within the coral tissue. Coral polyps, like humans, produce carbon dioxide as a byproduct. As the coral polyp releases carbon dioxide as byproducts of cellular respiration, the zooxanthella utilizes this carbon dioxide to carry out photosynthesis. The zooxanthella produces their waste products, sugars, lipids, and oxygen that the coral polyp feeds from. Within this extremely stable environment there are a plethora of wildlife that live among the corals. Many fish depend on the corals as a food source or as shelter from larger predators. A third of all saltwater fish will live part of their lives as juveniles among the corals. That is over 5000 different Western Atlantic native species that rely on the corals for shelter in their earliest stages of life. These juvenile fish are the exact prey the lionfish are experts at consuming (Bowen 2015).

Lionfish pose the biggest threat to the native juvenile fish that seek shelter among the corals. Their intimidating appearance and the name “lionfish” come from their unique hunting style. Unlike most predatory fish like the large grouper that will hunt individually, like lions on

land, the lionfish hunt in packs, or small schools surrounding a small shoal of juvenile fish. When the surrounded juvenile fish separate themselves from the shoal, the lionfish will one by one consume an entire shoal of fish. This unique hunting style has only been witnessed in marine mammals such as dolphins or orcas (Carr and Hixon 1995). Lionfish have voracious appetites and can consume twice their own body weight in a single meal (Carr and Hixon 1995).

Within these extremely stable environments it is imperative we protect these delicate ecosystems. When foreign human elements are introduced to the delicate ecosystem, such as plastic, rising global temperatures, or oil spills these variables can have devastating short and long-term consequences that may take decades or centuries to heal from. With the coral reef ecosystem under stress from many different sources, the addition of an invasive lionfish only further stresses the coral reef ecosystem. The lionfish tend to prey on many species seeking refuge within the coral reef. Lionfish have grown exponentially in the Western Atlantic due to many variables that will later be discussed. However, it is imperative that we involve all those who will listen to contribute in their own way to the hedging of this invasive species.

1.2. Public Awareness

Our local communities are an inheritance given to us by our families, neighborhoods, and local surroundings. However, we all belong to greater communities: our city, state, and country. Furthermore, when we discuss environmental issues, we are all part of the global community where we are all affected by what our global neighbors do. Environmental problems involve everyone around the local community and are inherently spatial. The environmental data and possible solution require the greater community and are also geographic in nature (Bailey and Grossardt 2007).

Mazzotti and Harvey (2015) surveyed tourists and Florida natives traveling through Florida's tourist destination hot spots in Orlando and Miami, and found that less than 12 percent of non-Florida natives were aware of the lionfish invasion within the Western Atlantic. Among Florida natives, the awareness of the lionfish invasion was found to be higher, which the authors propose was due to social media and local relief groups. However, most of the Florida natives did not know that they can contribute to the culling of the lionfish population through fishing. 52 percent of Florida natives were found to be aware that the lionfish is an invasive species, but only 17 percent knew that a fishing license is not required to remove a lionfish from Florida's coastal waters. This study shows that, although social media and the internet have increased the overall awareness of the lionfish as an invasive species, there is a gap between awareness and a call to action. With the public ability to fish for lionfish without a license will help contribute to culling of the lionfish population. Many different means of population control are necessary for the native fish population to flourish (Schofield 2017).

A sample of 508 respondents to the survey were avid salt water anglers. Salt water anglers, or salt water fishermen, fish for many different salt water fish species, in fact among the avid salt water anglers 87 percent knew about the invasive nature of the lionfish (Mazzotti 2015). Furthermore, these saltwater anglers must report all the game fish they have caught whether they released the fish or kept it through the National Oceanic and Atmospheric Administration (NOAA) mobile app. Saltwater anglers are used to reporting vital information through the mobile app because if an angler catches a bluefin tuna, swordfish and billfish reporting must be done within 24 hours of vessel returning from the fishing trip or suffer possible consequences. Although some fish like tuna and swordfish have reporting regulations as part of their permits, to control native fish populations. However, there is currently no NOAA or United States

Geological Survey (USGS) app to report lionfish. Commercial fisheries must report the amount of the fish they have the permit for, but also any other extra fish that were caught in their nets. These extra fish are known as bycatch. Based on bycatch sample data, we have reasonable certainty that the lionfish may also be thriving at deeper waters than can safely be investigated due to deep water pressure (Whitefield et al. 2006). Due to the specificity of this environmental problem there is a necessity to reduce this gap between the subject matter experts, and the lay citizen with a call to action. The use of an Esri Story Map aims to bridge this inherent gap with the aspiration to increase the call to action among the public. The difficult task is to reach the larger communities and inspire a call to action on a larger scale.

The smaller communities most affected by the lionfish invasion are all the coastal states along the Western Atlantic and Gulf of Mexico. The larger community includes the neighboring countries that share the same tropical waters. Lastly, the global community includes those Indo-Pacific countries where the lionfish are native. The Story Map created for this project is aimed towards the smaller communities around the Western Atlantic and Gulf of Mexico. The primary goal is to inspire a call to action among the local community to act in their own personal way. Even the smallest effort from the local community can contribute in a major way to the culling of the lionfish population. The secondary, loftier goal, is to inspire and perhaps plant a few seeds of inspiration within the global community and unite both the experts and lay citizen with a common purpose. For example, some Florida relief efforts are beginning to ship lionfish to restaurants and customers around the globe. The greatest benefit to involving the greater community is being able to work together for long term viable solutions.

The Western Atlantic reefs are the focus for several reasons: First, the lionfish are invasive only to the Western Atlantic. The Western Atlantic reefs are the only United States

main land reef ecosystem that should be preserved. Secondly, southern reefs, particularly around Florida, are of high commercial and recreational importance. Many livelihoods depend on the native fish within our Atlantic waters. A proper and engaging Story Map may help inspire commercial fisheries to begin fishing for lionfish. Some local communities in Florida are initiating movements to help harvest the lionfish from their local waters. Although these events are more for the smaller local community, we can all contribute as part of the larger community by purchasing the lionfish they harvest. Florida and coastal states are being encouraged to include lionfish as part of their menus to increase the demand for the fish to help keep their numbers in check.

Unlike terrestrial invasive species that can be tracked or monitored on land, tracking of aquatic species has other layers of complexity due to the vast ocean itself. Scuba diving is a popular activity among Florida natives and tourists alike. Among the scuba diving population surveyed 96 percent knew the lionfish was an invasive species (Mazzotti 2015). However, only 12 percent reported their lionfish sightings (Mazzotti 2015). The visual study of the lionfish is limited due to scuba regulations that don't allow any diving deeper than 100 feet without special equipment or permissions. Subject matter experts are missing a lot data about the lionfish if only 12 percent of scuba divers are reporting their lionfish sightings. A Story Map can further bridge the gap between the subject matter experts and the citizens who might have a vested interest in preserving the local Florida reefs like scuba divers and salt water anglers.

To properly engage the public in monitoring the invasive lionfish proper data must be collected. If the data could be easily submitted by the public through an easy to use mobile app, the subject matter experts would have larger sample sizes to properly gauge the lionfish population. Currently, to submit a lionfish sighting you must go to the USGS website and fill out

a detailed form (USGS 2017b). To fill out this form you must know the coordinates, type of fish and attach a photo or video proof of the sighting. These forms once submitted are then sent to Dr. Pam Schofield of the USGS for review. The complexity of submitting a lionfish sighting could be the deterring factor for most individuals. To properly map the lionfish distribution throughout the Western Atlantic it requires good data. Early data on lionfish within the Western Atlantic is fairly sparse beginning in the mid 1980's however, as their populations increased so did the number of sightings and the total number of lionfish spotted at one time. Accurate lionfish data is what we need to build captivating and publicly engaging maps. The data provided for this project by the USGS includes these early sightings as well as thousands of other sightings. The Story Map data for this project is based off of many individuals going out of their way to report the lionfish spotted.

1.3. Public Involvement

Ever-advancing technological improvements within the GIS space has allowed for the increased communication between the subject matter experts and the public. A Story Map is a new tool to help engage and inspire the public and to illustrate a story that helps raise awareness through its communicative possibilities (Esri 2017). Using social media and other interactive engaging platforms Story Maps can deliver a narrative quickly throughout the world.

The Story Map is a viable tool when public involvement is necessary. A Story Map helps to guide the user in a series of key narrative points that will walk the user through the key facts at their own leisure. Vivid images and interactive truly impactful maps help lead them to a conclusion point. With modern technology increasing screen time for all of us who carry a smart phone a Story Map can engage the public through this modern technology. The creative media of a Story Map includes all types of media from vivid pictures, to videos, documentation and even

interactive graphics to help tell the narrative. The multimedia approach is powerful to increase public awareness of the lionfish in our native waters. With interactive charts the Story Map, can portray and truly illustrate the impact the lionfish have had on our native waters. Furthermore, for the user the captivating nature of the images, video and interactive analytics will help keep them engaged as they consume the spatial story of the lionfish and their threat to our native coral reefs. Longer engagement through multimedia mediums will further increase public interaction with the Story Map increasing the overall reach of the Story Map. The interactive nature of the Story Map will lean towards our natural inclination to skip through the parts that don't interest us, and yet devour the sections of the story that are interesting. The user can customize their own experience with the Story Map as they click on the sections that interest them most.

The possibility of influencing individuals to the lionfish invasion and help raise awareness is a vital first step in creating change. If the proper story is told, the website with the Story Map, could essentially remain public to continue to raise awareness and possible create a public call to action. Although designed for the public the tool may also be used by wildlife management too perhaps add their own story, or help with continued management techniques. Using Story Maps will reach a far wider audience for the subject matter experts to reach the global community.

1.4. Data Acquisition

A subject matter expert (SME) proved vital in this project's direction. Dr. Pam Schofield from the United States Geological Survey (USGS) provided this project with valuable insight and the data necessary for the Story Map's development. A short interview was conducted prior to the project's commencement to properly gauge the project's direction and purpose.

Dr. Pam Schofield, a Florida native, has been studying the Lionfish invasion since 2004. During a virtual interview with Dr. Schofield although brief, proved to be very productive. Dr. Schofield, has always had a love for fish and knew as a child that she would study them later in life. Dr. Schofield studied invasive fish in Africa for her master's degree; later her PhD. was focused more on general ecology of the fishes around the everglades in south Florida. Dr. Schofield's expertise and advice shared about invasive fish and long-term involvement of the invasive lionfish proved to determine this project focus in creating a public awareness of the invasive lionfish (Schofield 2017).

Dr. Schofield's natural interest in the lionfish was peaked when Paula Whitefield of NOAA published a study in 2004 showing there was an established population of lionfish outside of North Carolina. Dr. Schofield was aware of the lionfish invasion and because lionfish were the first non-native marine fish to establish and spread within the local waters of the Western Atlantic, she began her research. In Pam's early memories with the lionfish invasion, it wasn't clear what government agency had jurisdiction so she cobbled together a team between James Morris of NOAA and Lad Akins of NGO to take leadership among this issue. With this team, they began collecting and sharing data (Schofield 2017).

Dr. Schofield stated that the lionfish was the first marine fish invasion but there are now 36 documented non-native marine fish that have been found around Florida alone. However, none of these fish have built up the population growth and spread equal to that of the lionfish. Dr. Schofield did mention her concern that if the lionfish was able to do it, other species could as well. She currently helps track and contribute to the USGS nonindigenous Aquatic Species database (USGS 2017a). Dr. Schofield's passion for studying the lionfish invasion is unparalleled as she truly enjoys her work. One of her last few comments was her concern that

there was a recent sighting of a lionfish as far south as Brazil. She described this sighting as a conundrum as there are many variables as to how, or why this lionfish has spread so far, so quickly (Schofield 2017).

Dr. Schofield also mentions in her closing remarks to our interaction that the public says things like; “there is nothing I can do” or “what’s the point, they have already taken over?” to that Dr. Schofield compared the lionfish to a weed in your yard. It is true that at times you cannot remove all the weeds, but when you pull the weeds you give the roses and other plants in the garden a chance to grow and flourish. When asked what the public can do to contribute, she mentioned, “that everyone can contribute to pulling the weeds from the garden in their own way. Yes, you will have to go out there and pull the weeds from the garden, but it will conserve certain areas providing many protected zones” for our coral reef and native marine fish to thrive (Schofield 2017).

In my interactions with Dr. Pam Schofield I had discussed my concern and passion that she too shares in raising awareness about this invasive lionfish in our local communities. Pam has spent more than a decade acquiring this valuable data and was willing to share the data for this educational project. Although the data was not prepared for use in a Story Map it has provided the right foundational data that one would need to create a properly developed educational Story Map (Schofield 2017).

Dr. Schofield’s involvement with this project, has been extremely influential in the project’s direction and definition. Public involvement and dissemination of data or findings from the subject matter experts through a Story Map can help everyone of the community contribute to weeding the garden (Schofield 2017).

1.5. What to Expect

The lionfish invasion has been closely focused on by several government agencies including, but not limited to the National Oceanic and Atmospheric Administration (NOAA) and the United States Geological Survey (USGS). The focus of these agencies is to monitor and track the lionfish invasion to better inform local wildlife management. The goal of NOAA's study of the lionfish is to, "minimize the ecosystems' degradation in affected sanctuaries" (Johnston, Gittings, and Morris 2015, 1). NOAA's continued long-term study of the invasive lionfish will focus on the possible long-term effects the lionfish may have on native reefs. The USGS and NOAA have had an early foothold in the study of the invasive lionfish and their growing population. However, most USGS and NOAA studies are not communicated to the public or intended for increasing public awareness to help create a public interest in conserving the community. While the USGS and NOAA scientists continue to study the lionfish and the long-term effects they may have on our native reefs it is important that we learn from other research on invasive species, similar characteristics can help identify critical issues that may help preserve our reef sanctuaries.

This research project aims to impact all those interested in preserving our native habitats and ecosystems from the experts at NOAA and USGS to the lay citizen. The next chapter briefly covers other successful Story Maps that included public awareness with successful results. The following chapter will also illustrate the success of those Story Maps as well as the data differences between lionfish data and typical fish data.

Later chapters will dive into the project's definition and the story board steps involved in creating the lionfish Story Map narrative. The third chapter will also discuss the many steps taken to prepare the data for the appropriate ArcMap tools to create the different maps within the

Story Map. Media collection and map creation will be discussed in Chapter 4 which will highlight what media was used with the intended purpose within our lionfish narrative. Lastly, the concluding chapters will discuss the results of the Story Map among a small sample size group, and their respective feedback.

Chapter 2 Related Work

This chapter's purpose is to establish a background of how effective a Story Map can be while also representing the potential threat of an invasive species possibly leading to the extinction of native species. Story Map tool is fairly new, but the Story Maps reviewed in the section will highlight their usefulness in informing and engaging the public. With the proven success of other Story Maps this project aims to engage the public regarding the invasive lionfish.

2.1. Invasive Species

Simply stated an invasive species is any animal, plant or in this case a fish that is not native to a specific location. Typically, invasive species are believed to cause damage to the local ecosystem. Invasive species are typically introduced by some form of human interaction. The root of most invasive species indicates that humans introduced the foreign species either on purpose or accidentally (Miguel Clavero 2005). This accountability also requires our need to monitor and solve the problem where possible. Some believe that invasive species have led to the extinction of some native species.

Clavero and Garcia-Berthou (2005) researched the hypothesis that invasive species were the leading cause to extinction of native species. In their study of over 680 well documented extinctions, 54 percent of animal extinctions were the direct result of an invasive species. Extinctions were the combination of an invasive species and the result of over harvesting and habitat destruction. However, when the extinction species is broken out by type of animal, birds, fish and mammals the results are grim for aquatic species (Clavero and Garcia-Berthou 2005). Table 1 shows the results from their study indicating that aquatic species were less likely to adapt to an invasive species. This impact is amplified further if habitat destruction and over harvesting of native species are considered (Miguel Clavero 2005). The Western Atlantic has seen a decline

in native species due to over harvesting and is the main reason why NOAA requires reporting of the fish caught with certain permits. Overharvesting and an invasive lionfish are the recipe for native species extinction according to Clavero and Garcia-Berthou.

Table 1. Extinct animal types due to invasive species

Extinct Animal	Percentage of Extinction due to Invasive species
Birds	50%
Fish	67.5%
Mammals	48%

2.2. Public Participation with Story Maps

The main objective of this project is to develop a simple yet effective Story Map that will empower the public and inspire them to action. With many more people aware of the lionfish invasion it is the goal of this project to inspire other theories like those posed by the master divers trying to create a taste for lionfish among the apex predators. Creative ideas such as these can only be rooted with the inspiration to preserve our natural resources. Pam Shofield a Florida native and lionfish invasion subject matter expert, has been studying the Lionfish invasion since 2004. Through the aid of the USGS and specifically Dr. Pam Schofield, the author was given the lionfish data dating back to 1985. This database is a compilation of records received from governmental and private sources for the United States and Caribbean nations (Johnston and Purkis 2011). With this data provided by the USGS, we can visualize the population flow and distribution of the lionfish throughout the Western Atlantic and Caribbean waters. The

distribution flow maps created could then be used to chronologically map the lionfish geographical distribution throughout the Western Atlantic.

2.2.1. What Is a Story Map?

“Story Maps let you combine authoritative maps with narrative text, images and multimedia content” (Esri 2017). They provide an online platform for individuals and organizations to bridge the gap between the subject matter experts and the everyday citizen. However, the online GIS content is gated behind expensive licenses that may hinder smaller organizations from utilizing this valuable tool to share their results with the public. The license empowers the organization to create a cloud based repository for many interactive maps that can be used by any group to disseminate their narratives.

2.2.2. Public Participation

Story Maps can be built with many purposes or goals one of which is to inspire public participation. In San Diego, the Mission Bay Marsh Reserve Story Map, created by UC San Diego, was designed to empower the public. The marsh is a nursery for many native fish and oceanic crustaceans that proved vital for the local ecology (UCSD 2015). Furthermore, the marsh’s unique environment is a breeding ground to several native birds that rely on the calm waters of the salty marsh. The marsh was under the potential threat of being built upon by local developers, and the Story Map was used to empower the public to better educate them in their voting decision. With proper marketing and an informative Story Map the marsh was voted to be preserved as a wild life sanctuary within the city limits of San Diego. The power of the public’s involvement and the power of a Story Map, should not be underestimated.

The concept of building a Story Map with the sole purpose to inform and involve the public has been exercised by other organizations with fruitful results. The National Capital

Commission (NCC) is one of the principle stewards of the environment throughout Canada. The NCC created a Story Map to involve the public to help remove some invasive plant species around Mud Lake. Mud Lake is a natural habitat for many plant, mammalian, reptilian and fish species. However, due to human interaction the invasive plants were introduced and now smothering the native plants that some species required for shelter and reproductive purposes. Within one year of NCC launching their Story Map, the NCC recruited 59 volunteers from local students and business partnerships. All the volunteers contributed well over 200 hours to the manual removal of the invasive plant species surrounding Mud Lake (NCC 2015). The volunteers controlled over 6400 square meters of invasive plant species around Mud Lake, with more than 120 kilograms of invasive plant species physically removed from Mud lake, thus clearing the way for native species to take hold.

The success of volunteers and the ongoing maintenance of Mud Lake is important to take note of here within our community of the United States as well. Some of these invasive aquatic plant species that the volunteers are helping to remove around Mud Lake, have found themselves on neighboring states that share the same waters as Canada. Recently, the invasive species plant, starry stonewort has been recorded on the coasts of Minnesota. Starry stonewort is a invasive threat due to the nature of the plant creating a carpet that smothers native plants not allowing native plants access to light (Marcotty 2015).

2.3. Effective Story Telling

The Story Map concept has only but recently emerged with the power of cloud computing. However, to properly tell the story of the invasive lionfish there are some important basic storytelling, or communication principles that should be considered. A strong impactful image will help lure onlookers to view the narrative being shared, this will continue to bring

people into the story. The viewer needs to know immediately where the story takes place through impactful images and media. The core concepts regarding the lionfish invasion should be at the beginning of the story to inform and maintain proper viewer attention (Riefstahl 2011).

Outbound links should be avoided at the beginning and should be included at the end of the Story Map because the point of the story is to keep their attention on the narrative. External links will simply detract their attention and will possibly end the viewer's session (Riefstahl 2011).

An effective Story Map will need to consider their target audience throughout the presentation. All text, media and maps will need to further focus on the target audience. For example, maps targeting the public should be simple and clean. Contrastingly, if our target audience was to other GIS specialists the narrative would allow for more intricacies (Riefstahl 2011).

As Steve Jobs stated in 1997, "Because the people who are crazy enough to think they can change the world are the ones who do." This quote emphasizes the impact of inspiring a single viewer to change the community, possibly the world. Every detail in designing media and maps for telling the lionfish story to a targeted community audience must be considered. Rousing the viewers to act through inspiring maps and images tied together with a strong narrative. Too many details on a single image or map may confuse the viewer, thus lowering the effectiveness of the image or point being made (Riefstahl 2011).

Modern technology has led to many communication advancements; with our smartphones, we can access information that used to only be limited to a desktop computer. Within this new digital age attention spans are shorter and an effective Story Map must maintain the viewers' attention despite the challenges of today's technology (Kenny 2009). Figure 2 highlights this idea indicating the simpler you make the message the more effective your

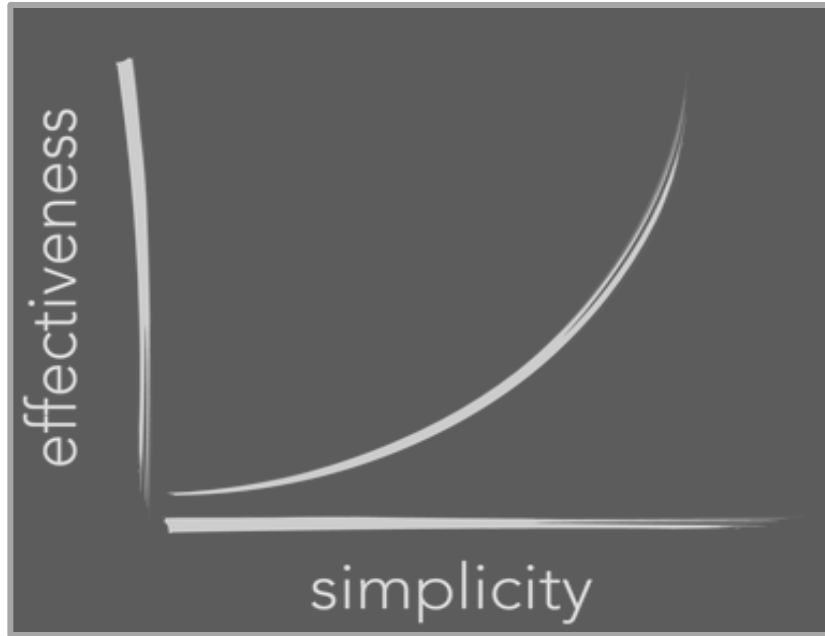


Figure 2. Simplicity Equals Effectiveness

message becomes. Due to the shorter attention span of our digital life style if an image or map looks very complex from the first initial impression, the user is more likely to skip or bypass the true value of the message being delivered (Kenny 2009). The greater the complexity of the media is often over looked and bypassed by the viewer due to the intricacy. For example, within our lionfish Story Map there are thousands of features and data points that need to be broken down into simple digestible maps that the end user can consume at their own pace. The difficulty of making complex data simple is where the challenge lies for the subject matter experts. Often when you are immersed in a story or narrative it is hard to see if is being created is “simple.” Thus, emphasizes the value of other opinions when building a proper Story Map.

Flow maps are used to show movement of goods or people from one location to another. These maps are engaging and will help captivate the viewer. For example, Figure 3 is a map created by the well-respected economic cartographer, Charles Minard, in 1858. The map charts the many emigrant destinations during the late 1850s (Minard 2008). Minard is often credited for

his uncanny ability to convert large amount of data into understandable maps. This map is powerful and easily interpreted. The larger lines indicate more emigration movement, whereas the smaller, thinner lines indicate less emigration to the respective countries. It is important to note that the actual shapes of the continents are not geographically accurate, but Minard's objective is to highlight the emigration movement around the world with the weight of the distribution flow lines taking precedence over the accuracy of the continental shapes. Each color indicates a different country representing the emigrant's country of origin.

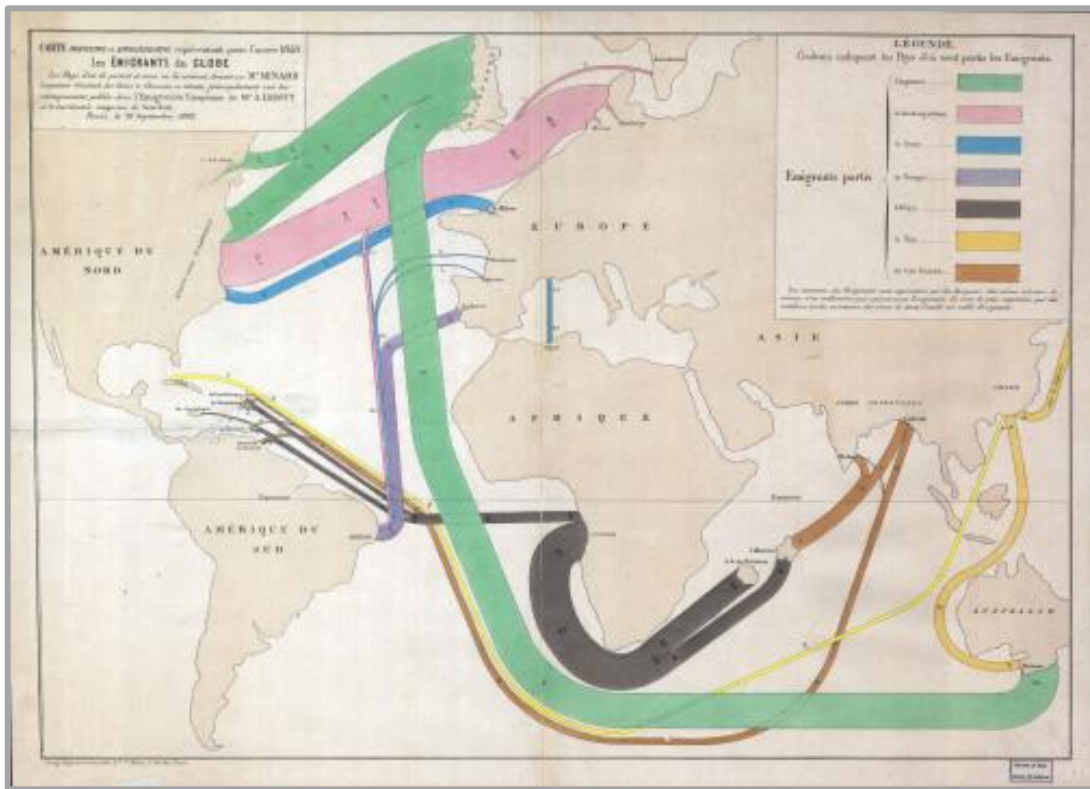


Figure 3. Charles Joseph Minard's Emigration Map Year 1858

2.4. Lionfish Population Control

Controlling the lionfish population requires many active layers simultaneously working together. The lionfish are very adaptable and have also been found many miles off-shore where

the ocean tends to shelf. These are prime locations for other species such as crab and lobster. Lobster fisherman also catch lionfish as they enter the lobster traps in search of an easy meal, but then are hauled up by lobster fisherman as bycatch. A single fisherman has reported over 6,000lbs of lionfish bycatch in a single year (Johnston, Gittings, and Morris 2015). When a lobster fisherman accurately records their lionfish bycatch data, Florida provides a small incentive for them to haul a few extra lobsters as part of their daily limit. The added benefit of recording the bycatch data with the lobster is to accurately determine the depths at which the lionfish are being caught. Lobsters are on the sea floor at depths far greater than divers are capable of diving without special equipment. This data allows proper depth documentation of lionfish.

Another layer working to control the lionfish population that does already include the public are lionfish derbies (Green and Cote 2010). In the Florida Keys sanctuary, in 2010, the wildlife management held Lionfish Derbies, where the derby participants were trained how to safely fish from the sanctuary waters. Armed with a fishing spear volunteers would dive the shallow waters and spear the available lionfish for human consumption. Every lionfish has their data is recorded, and the derbies are a regular occurrence to help keep the lionfish population under control. While the lionfish derbies are helpful in lowering local populations, they are restricted to only shallow waters. However, the ecological impact of the lionfish derbies is minimal in the grand scheme of things. These intense removals are helpful to the local restaurants as they have been encouraged to include lionfish on their menu's as the white meat is supposedly very succulent and tasteful. Through a properly designed Story Map, the participants of the local lionfish derbies may begin understanding the ecological impact they are helping with while they remove the large number of lionfish in a single derby session. Furthermore, if the

public were to feel inspired through social media they can share how they are contributing to help clean the environment thus creating the vast communication web necessary to help control the lionfish populations.

Most lionfish derbies are successful because derbies are typically around coastal waters. Thus, the physical removal of lionfish through the lionfish derbies around the coast not only make it safer for recreational use, but increase public awareness of lionfish presence. Around the Florida Keys, the aquarium trade is also capturing the invasive lionfish and are selling them through aquarium trade distributors. This is helping to not import any more lionfish from the Indo-Pacific. (Johnston, Gittings, and Morris 2015, 1) Similarly to the volunteers around Mud Lake, the volunteers or participants in the lionfish derbies and members of the aquarium trade, help to physically remove the invasive species from our native waters.

Lionfish derbies and bycatch recordings are effective means of management but they are not tools for the experts to monitor and manage the local lionfish populations. The public has nominal knowledge of the impact these lionfish are having on our local coral reefs. Wildlife management consider lionfish eradication highly impractical due to the species already established distribution. The best strategies from NOAA and ONMS (Office of National Marine Sanctuaries) are to increase public awareness as the lionfish continue to pose a threat to local scuba and snorkel divers. Raising awareness will help minimize the risk recreational divers, snorkelers and even swimmers because of the venomous spines the lionfish possess. Sustained public awareness may possibly increase public participation.

Further outreach and sustained public awareness could create public ripples that may lead to greater management plans. Recently, research is underway to help create a ‘taste’ for lionfish among native apex predators within the Western Atlantic and Caribbean reefs. The theory is

based off the natural predators of the lionfish in the Indo-Pacific. Local divers are attempting to give native groupers, sharks and other large fish to consume the lionfish. Similar predators are natural predators to the lionfish in their native waters to help keep that help keep their populations in check. Part of the explosive growth of the lionfish here in the western Atlantic waters is due to the lack of natural predators. One of the ideas founded by the public was to spear the lionfish and feed the speared lionfish to the local apex predators to help create a “taste” for the lionfish, so they will recognize the lionfish as prey (Busiello 2011). If these native apex predators begin to see lionfish as prey their numbers may be kept in check to help balance the ecosystem. Although this is not encouraged by any government agencies recreational master divers continue to pursue this philosophy. Time will tell if the long-term effect of this theory will prove fruitful.

Chapter 3 Methods

This research process was guided by a small group of volunteers with the goal of influencing the local community in mind. The volunteers had no prior knowledge to the lionfish invasion prior to volunteering to provide feedback on this project. The volunteers helped with the direction of the map content, media materials and media placement within the Story Map. I continued to update the maps according to their feedback. Data preparation was essential to utilizing the proper ArcMap tools associated with producing the different population maps desired for this Story Map. This section provides insight to the differences between typical fish data and lionfish data and the data preparation steps used to create the maps used in the lionfish narrative.

3.1. Project Definition

Prior to this project, there was no affiliation with the USGS or NOAA, nor was I contacted by any academic partnerships. This research depended solely on independent research and communication outreach efforts between myself, NOAA and the USGS. The communication outreach took about 12 months to establish a communicative dialogue between myself and Dr. Pam Schofield from the USGS who provided the lionfish data. The lionfish data acquisition proved to be more challenging than expected, which provided some constraints within the project's overall timeline. This section provides insight to the different sequential phases needed for this project.

Most projects begin with a clear understanding of the different phases needed to complete the mission. Although the objective of completing an inspirational Story Map remained unchanged the incremental mile stones evolved throughout the project's life cycle. This project's phases evolved as the project advanced through the many different challenges. The three clear phases that remained unchanging were (1) Data Acquisition and preparation, (2) Map Creation

based off the data, and finally, (3) Multimedia selection. Originally the timeline allotted was a six-month timeline allowing for a generous two-month time each of the three different phases, however the project began late with data acquisition taking longer than intended. Upon data acquisition however, the renewed timeline of six months was reestablished for the completion date of this project. Each two-month phase was built upon the prior and required the appropriate building blocks to construct upon. These clear target dates helped keep the project on pace for completion.

Interdependencies among the different phases required the phases to be completed sequentially versus simultaneously like some other projects. For example, the maps could not be created without data acquisition and preparation prior to building the maps. Due to the interdependent nature of the Story Map, different mile stones were established by the project outline to ensure project progression throughout the project's timeline. Three major mile stones were established based off the phases originally outlined from the project's commencement. First, data acquisition was the primary building block of the entire project and took the longest to complete. Upon acquiring the data clear goals allowed for efficient data preparation for the maps to be developed. Next, map creation was the second major milestone needing to be reached to ensure the project's timely completion. The Story Map consists of vivid multi media and the selection of the media was selected around the lionfish narrative. The final mile stone, dependent on all the previous building blocks, was the completion of the Story map script which illustrated where the maps and media would be with the accompanying text.

Although the research on this project is extensive there were some monetary limitations. Since this project is a student based research project there was no funding to visit the locations

that were researched or purchase publicly available data. Thus, relying on subject matter experts for data and their insight on the invasive lionfish.

3.2. Story Map Template and Contents

To properly convey the lionfish narrative story to those without prior knowledge of the lionfish invasion, it is imperative the proper Esri Story Map template is chosen to help engage, entertain, and educate our viewers. Esri, the creators of the ArcGis Story Map, have provided many different templates to help tell our story. All the templates are slightly different and provide a unique set of engaging tools that need to be considered to best engage our audience. This section provides insight to the differences between Story Map Templates and some of their uses.

Based on project goals and direction of the Story Map narrowed down the Story Map options down to three potential templates. These options were considered due to their flexibility and narrative delivery methods each unique to their respective designs. The Story Map Spyglass template was considered as it was captivating and it would allow the user to view more details of

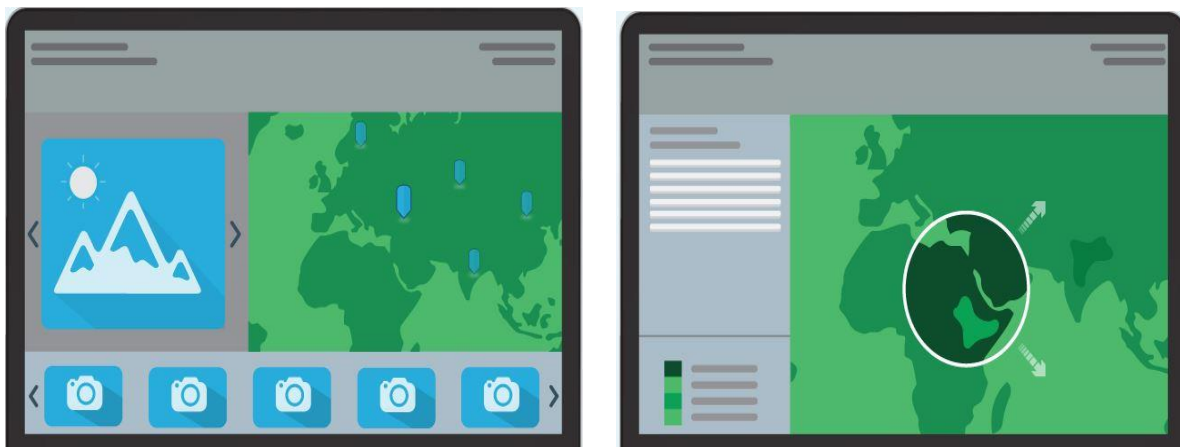


Figure 4. Story Map Templates Tour and Spyglass

the provided media with a spyglass tool. This is especially helpful in delivering a before and

after map (see Figure 4). The principle reason this was not chosen was we wanted to tell a gradual story of the lionfish invasion over several years compared to a before and after. Although the dramatic impact this template provides in highlighting pre-lionfish and post-lionfish invasion is beneficial, the template was not conducive to tell the whole narrative. The next Story Map



Figure 5. Story Map Journal Template

template was the Story Map Tour template (Figure 4). This template was favorable due to the sequence of photos or media that could be linked to a map. The primary function of this template was to provide the media through an interactive principle map; our narrative planned on utilizing multiple maps in our Story Map. However, the final template, and the one utilized for this project was the Story Map Journal template (Figure 5). This template had the capability of including multiple interactive maps without distracting the viewer while keeping them engaged. With a simple scroll of the user's mouse or swipe of the finger, the template allows for full immersion with multi-media integration throughout the narrative. Lastly, the Story Map Journal provided the user with the best interaction of a narrative column and simple selection to open videos,

enlarge photos, or transition into different sections of the map. This provided the best launchpad for our Story Map.

3.2.1. Story Map Topic Flow

The project's goal was clear from the beginning, inspiring the public to participate in the solution of the lionfish invasion. However, the topics to include within the Story Map evolved throughout the creation of the project. The original project was outlined using a story board with sequential images and topics that would later be expanded to fully develop our lionfish narrative. The story board outline focused on three major questions. (1) With the lionfish invasion, what is at threat? (2) What keeps the lionfish population in control in their native Indo-pacific waters? (3) What can the public do to help? To fully impact the viewer the user must first understand what is at threat. Maps and media help draw the reader into the lionfish narrative as they first understand what is at threat.

Illustrating what is truly threatened by the lionfish invasion was highlighted by illustrating vulnerability of the sedentary corals and the juvenile fish that seek refuge within the coral reef structures. Macro images of corals were used to draw the reader under the water and immerse



Figure 6. Macro Image of a Small Polyp Stony Coral

them into the life of a coral (Figure 6). The lionfish Story Map also highlighted the unique hunting nature of the lionfish as this fish hunts in a group compared to other predator fish. Video media was also used to show the unique hunting style of the lionfish as they threaten the native fish within the coral reefs.

Lionfish are native to the Indo-Pacific and are not decimating local reef fish populations within their natural habitat. The Story Map aimed to highlight the vast difference between the Western Atlantic reefs compared those reefs located within the Indo-Pacific. Two major topics were highlighted when addressing the lionfish's natural habitat. First, the reefs of the Indo-Pacific cover a much larger area when compared to those of the Western Atlantic. With more Sqkm of corals the lionfish have less of an impact compared to the much smaller Western Atlantic Reefs. Secondly, the larger predator fish within the Indo-Pacific recognize the lionfish as pray, where the larger groupers and sharks within the Western Atlantic do not. Highlighting the differences of the lionfish's natural habitat compared to the smaller more vulnerable Western Atlantic reefs creates an opportunity for the reader to want to contribute.

This small moment when the reader chooses to contribute is how the project ends, with multiple options for the reader to contribute in their own way. The last topical question of how can the public help is addressed by introducing what others are doing to contribute. First, the controversial topic of feeding a lionfish to local native Western Atlantic predators with the hopes of creating a taste for the lionfish as pray is shown with vivid images and public video. Understanding, that most of the readers will not be as adventurous as these divers who are feeding the local predators, the Story Map concludes with the reader having multiple options to contribute in their own way.

3.2.2. Media Collection and Selection Process

The value of this Story Map is that it educates and encourages the public to help and contribute to the maintenance of the lionfish population. Captivating images engage the Story Map viewer to help sew these seeds. High definition media and simple text will grab and maintain the viewers' attention. Phase one of media acquisition was to find the high-quality images, video and macro images to help tell our narrative. Dr. Pam Schofield was helpful in inspiring the images necessary for telling the harsh truths of the lionfish invasion. Suggestions included showing the lionfish in their invasive environment surrounding their prey, and illustrating the mass consumption these predators are capable of.

Lionfish are having a major impact on Florida native reefs, so to best tell their invasive narrative it is pertinent to use high impact media. The media to best tell the lionfish narrative will be broken into three categories. First, high definition images will draw the viewer in and maintain their attention. Secondly, high definition video will show underwater footage of the lionfish to further impact our viewer. Lastly, high definition macro photography, which is an extreme close-up photograph that will highlight corals, reef fish, and lionfish in their natural environment.

Media collection was completed over three months, with the first month dedicated to gathering high definition images of the lionfish without filters. The goal was to have a vast database of images to sort through that would best tell the lionfish narrative. The second month was dedicated to finding high definition public videos, also without filters, that would also help share the lionfish story. The beginning of the second month, the mass library of high definition images and videos were selected to a final fifty images and ten videos that could be utilized within the Story Map. Macro photographs were selectively collected that would give us extreme

close up images on both corals and lionfish. Table 2 illustrates the timeline over the three months used in media assembly and assortment.

Table 2. Phase One Media Collection and Selection

Media Type	Month 1	Month 2	Month 3
HD Images	Collect HD Images referencing the Lionfish invasion	Sort HD Images that best share the lionfish narrative	Final selection of HD Images for Story Map creation
HD Video	Collect HD Video referencing the Lionfish invasion	Sort to 2-3 HD videos that best share the lionfish narrative	Finalize HD video that would later be utilized in the Story Map
Macro Images		Selectively find appropriate macro images	Finalize macro images for focal points in Story Map

In recognizing that the government organizations NOAA and the USGS have actively been involved in tracking the invasive lionfish and have provided many articles and journals for the fundamental research this project. Dr. Schofield’s experience, lionfish database, and helpful direction proved pivotal in this project completion.

3.3. Lionfish GIS Data Preparation and Map Creation

3.3.1. Description of Map Types

This project focused on three map types to fully illustrate the lionfish narrative. The Distributive Flow map and the Population density map required some data preparation prior to

map generation. The data preparation was to allow for the ArcMap tools and calculations to properly function and display the created map. First, the Distributive Flow Map was created to simulate the Minard’s flow map (Figure 3). Secondly, Population Dot Density (or dot-distribution) or thematic maps use dots to randomly show population patterns across an area (Smith 2008). The distribution of the dots allows this map to display where the mass populations of lionfish exists by also scaling the dot to indicate larger populations. Finally, the Coral Reef map will require no extra data preparation, but will utilize standard tools within ArcMap. This section provides an understanding to the differences between typical fish data and lionfish data with the data preparation steps used to create the Distributive Flow map, Population Dot Density map, and the Coral Reef maps used for the lionfish narrative.

The maps created for this narrative were produced to serve a specific purpose. The Distributive flow map was created to be the opening map of the story map and properly illustrates the spread of the lionfish throughout the Western Atlantic. The Population Dot Density map creates a moment of true engagement by the reader, providing them with an individual link of each year to interact with to display that respective years Population Dot Density map. The maps and their corresponding purpose are shown in Table 3.

Table 3. Maps Created with their purpose in the lionfish narrative

Map	Purpose
Distributive Flow	This map clearly illustrates the development and spread of the lionfish population and is used to open the Story Map
Coral Reef Coordinate	Detailed coordinates of known Coral reef locations throughout the world
Coral Reef Sqkm	Detailed area rasters that highlight the world’s Coral reef densities

Chronological Population Dot Density	The user can interact with each year from 1990-2014
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3.3.2. Data Issues

The collection of lionfish data is unique in that it depends highly on community involvement. Typical fish population data is measured in gross weight, which is how commercial fishermen report the amount of fish they have caught in a single haul (Schofield 2009). However, with the lionfish the data collection process is different. The lionfish were first reported as sightings by the local community to the USGS. For example, a local scuba diver or fisherman would report the lionfish on the online form provided by the USGS. The scuba diver would report when and where they spotted a lionfish, while hopefully recording the coordinates of their location (Schofield 2017). These sightings were rare at first however, with the increased populations of the lionfish the sightings have been increasingly frequent. With the rise in lionfish populations lionfish data is slowly transitioning over to the second form of fish data collection which is bycatch.

Fish bycatch, in the fishing industry, is fish or other marine species that is caught unintentionally while catching a target species (Dodge 2015). In other words, a lobster fisherman may catch lionfish as bycatch when fishing for lobster. Lionfish bycatch among fishermen, both recreational and commercial, has been increasing as fishermen are required to report any bycatch to wildlife management such as NOAA or the USGS. For example, with tuna there are regulations in place that prohibits any more fishing after 40,000 tons of fish have been caught (Greboval 2003). These hauls are recorded within 24 hours of the vessel returning to the docks. These reports are great indicators for wildlife management to properly open and close out the season based off commercial fishing hauls. The data provided by the USGS for this project does

not distinguish any bycatch data so the assumption must be made that all the coordinated lionfish data is based of sightings and not by bycatch numbers.

The Indo-pacific lionfish have spread quickly throughout the Western Atlantic and Caribbean waters, producing a marine invasion that has not been recorded before. The lionfish invasion is unparalleled in speed and magnitude, these marine invaders are a growing concern for the balance of the entire ecosystem. Due to the predatory nature of the lionfish there is no clear data on the native fish species before and after the lionfish presence. Lionfish hunt in schools and have been known to decimate entire shoals of reef fish.

The simple data point indicating a sighting of a single lionfish or a small group of lionfish, versus the tonnage of fish hauled, such as typical bycatch data, has an important factor to play in the lionfish narrative. The sightings of lionfish were recorded as a raw number of how many lionfish were located or caught by the individual submitting the report. Not until 2004 were lionfish numbers significant enough to begin recording their numbers in biomass. The lionfish are voracious eaters with enormous appetites, thus recording of the biomass of the lionfish further helps to understand the possible amount of fish the lionfish has consumed when the individual lionfish was caught. Although, most lionfish are still recorded individually, the data of almost every lionfish is recorded to further help with the long-term study of the possible consequences these invasive fish may have on our native coral reefs.

Marine biologists and other marine scientists are typically the only people tracking lionfish and collecting data. Unlike many avian or terrestrial species that may be tracked visually over a short period, or with modern technology like GPS tracking, aquatic species are typically hidden from us. Despite advancements in satellite technology, satellite imagery is still in its initial stages, limiting the depth and detail that we can monitor these fish populations. GPS

tracking technology typically only proves useful in tracking large mammals or fish that surface frequently, such as whales or dolphins. Lionfish observation is typically done by scuba divers, or commercial fisheries that happen to catch lionfish as they fish for other native species within the same area. In this case, they are considered bycatch. When lionfish are caught as bycatch the numbers are still recorded, but the biomass of the individuals is not. Commercial and recreational fisheries must report their bycatch to further enhance long term research. Typically, lionfish bycatch data is not recorded in their aquatic habitat because they are caught in lobster traps or fishing nets that are drug across hundreds of miles of open ocean, making it nearly impossible to accurately assess where the population data originated.

3.3.3. Data Processing

Finding and acquiring the data took well over 12 months of constant communication attempts with NOAA and the USGS. Multiple attempts were made to reach individuals at NOAA and the USGS, through the organizations *contact us* link on their respective websites. Upon reading an article that summarized the invasion of the lionfish by Dr. Pam Schofield, attempts were made to find her on social media, such as LinkedIn, with the hopes of beginning communication with regards to acquiring the lionfish data needed for this project. All avenues of social media proved to be a dead end. Finally, three months after submitting an inmail through LinkedIn to Todd Kellison from NOAA, he responded who later introduced me to Dr. Pam Schofield at the USGS via email.

Dr. Schofield's hesitation on sharing her data with a driven persistent master's student was merited. She has spent many years collecting and organizing lionfish data for her organization. Dr. Schofield shared in an interview, that she has created many maps over the last ten years of the invasive lionfish. It was, also mentioned that she had not yet been exposed to a

Story Map and was open to reviewing one through this project. It was later discovered that there was a common interest in empowering the public to become more involved in weeding the garden of the lionfish. With the project’s commitment to empower the public and increase public engagement, she willingly shared her data that she had spent the last thirteen years collecting.

3.3.3.1. Data Preparation for the Distributive Flow Map

The preparation of the data for the Distributive Flow Map took many variations as the data provided by the USGS was in a comma delimited format which needed to be prepared differently for each respective map in ArcMap. Organizing the data to create a distributive flow

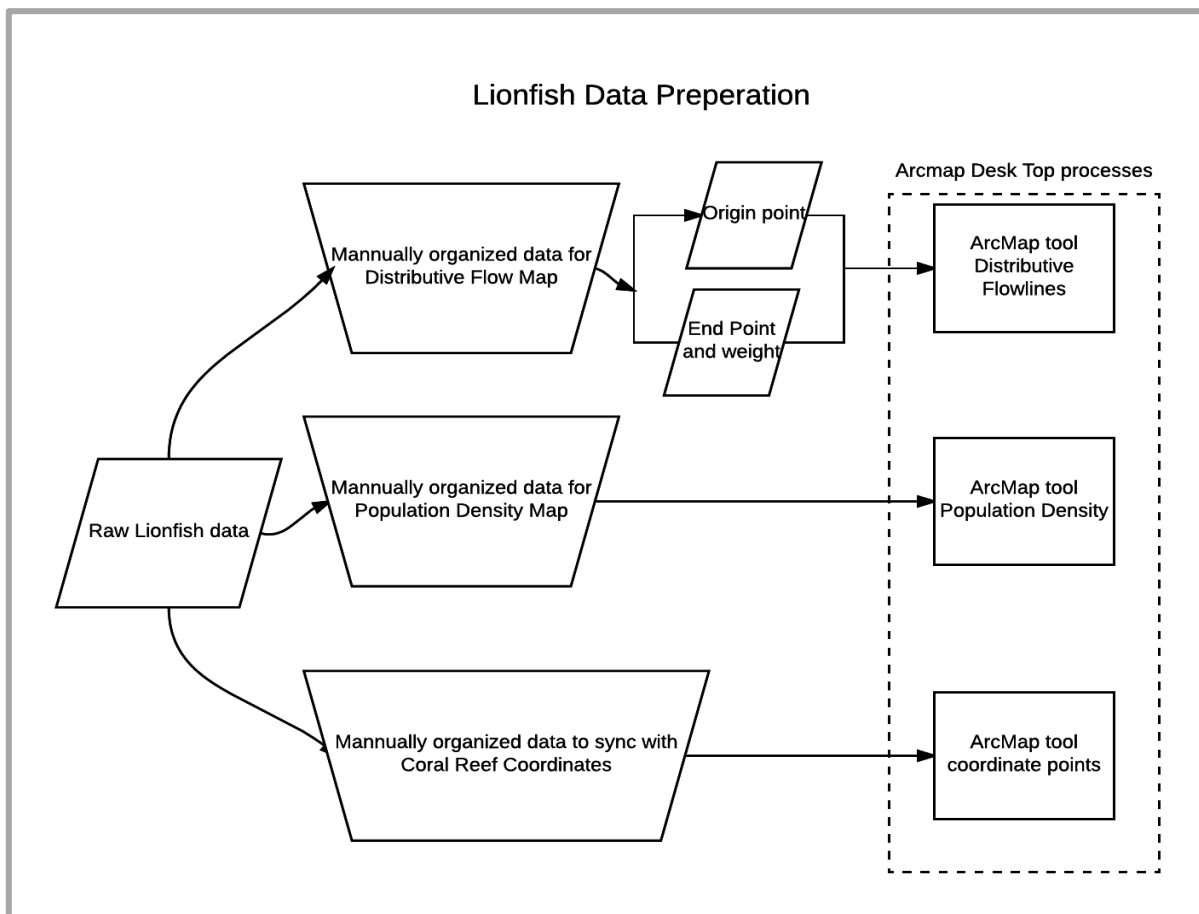


Figure 7. Data Preparation

map was top priority. Figure 7 shows the workflow of preparing the raw data to function properly within ArcMap to build each respective map according to the ArcMap tools.

Dr. Schofield shared a very large Excel (CSV) file with well over five thousand records. Each row had a plethora of information from the coordinated data on the location of the lionfish sighting, to the species of lionfish spotted and how many lionfish were recorded. The vast spreadsheet was primarily organized in chronological order, based on the date of the lionfish being reported. However, there was a need to reorganize the data to fit this project's objectives. Principally, the spread sheet needed to be restructured into separate tables. The need for new tables was to identify the origination point, or the first lionfish sighting, to allow the ArcMap tool to properly calculate the distributive flow of the lionfish

To run the ArcMap tool a feature class with a single point, or the origin point needs to be separated to import the feature set apart from the destination feature sets. The origination point used was the first sighting on the spread sheet recorded in 1985. Once the origination point is separated other destination tables were created. The destination feature classes also contained the attribute that the magnitude of the values will be calculated by, in the case of the lionfish I used the population data field. This population field when calculated through the ArcMap tool will specify the width of the lines, or indicate the magnitude of the values. The creation of the distributive flow maps required a special calculation tool provided by the University of Southern California. Figure 8 indicates the steps necessary for the ArcMap tool that takes source and destination features and converts them to points. With this point data the tool uses the **Create Fishnet** tool, which will ultimately give the finished flow lines some structure and converts that grid back to points (Prasead 2012). Next, the specialized ArcMap tool creates three Euclidean distance rasters when you run this toll (Prasead 2012). The first raster is based on the distance

from the source, or the origin point. The second raster is based off of the destinations, and the final raster is based on the grid centroids (Prasead 2012). After the rasters have been created the tool can now run the **FlowAccumulation** tool to determine the quantity or the weight of goods, which then converts the output to vector lines with weighted values (Prasead 2012). This tool is called the **FlowMapGenerator** within the ArcMap toolbox displayed in Figure 8. All the complexity and robust calculations behind this specific ArcMap tool have been programmed to help recreate some maps by the idolized Charles Minard (Figure 3).

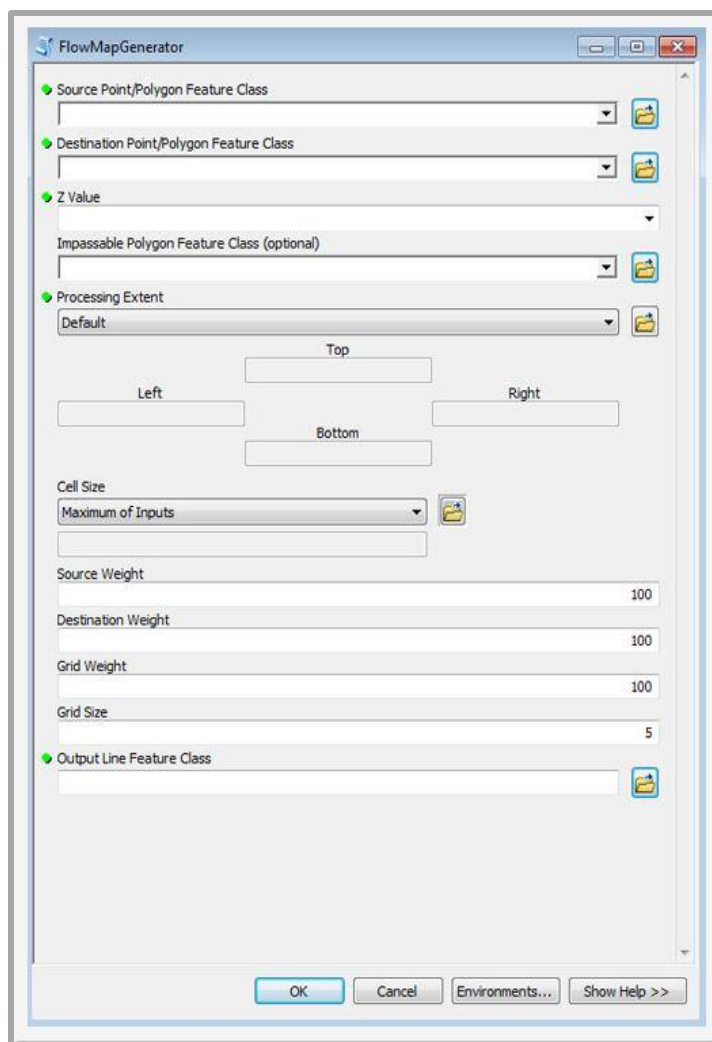


Figure 8. Flow Map Generator - Specifically designed for Distribution Flow

The population data for the lionfish was also used to indicate population flow of the lionfish to different destinations. The lionfish data can be modeled similarly to Minard's model, as we have a conclusive origin point in 1985 just off the coast of Miami indicated by the red star in Figure 9. The different destination points, or end points, were then weighted by the given population data. These two data sets were processed through the ArcMap tool **FlowMapGenerator**, which used the origin point to then branch out to each end destination creating a thicker line with higher population numbers.

Some aspects of this map stand out visually. For instance, the thickest lines are those that are traveling to the Caribbean waters. This demonstrates the possible conclusion that lionfish prefer warmer waters. The narrow line leading as far north as New Jersey could indicate the lionfish's adaptability to live in different temperatures. The map shows the exponential growth of the lionfish beyond the year 2000, as lionfish numbers began to almost double every five years. Overall, the map demonstrates the flow of lionfish throughout the Western Atlantic and Caribbean waters since 1985.

3.3.3.2. Data processing for the Dot Density Population Map and Coral Reef Maps

The lionfish data was then prepared for the Population Dot Density map to indicate the different sightings per year. The data was scrubbed by eliminating the null factor fields, the blank fields that did not have any population data, which was less than 300 records or less than 5% of the total data set. Next, the data was separated chronologically to properly compartmentalize the data by year. The Dot Density data preparation was minor in comparison to the Distributive Flow map. The Coral Reef data was a feature set of coordinates and was imported directly to ArcMap with no edits. The Coral Reef map and the Dot Density map utilized native tools within ArcMap and required no special ArcMap toolbox calculations.

Figure 11 indicates the lionfish population density data around Florida, larger populations of lionfish are indicated by larger dots in the given area. This map synchronizes with the Distribution flow map, and highlights the rise in population of the lionfish after the year 2000. Mapping the lionfish population through distribution flow or dot density maps over the last three decades inevitably shows the lionfish increase in numbers, thus raising their threat to native fish and wildlife.

The preparation and finalization of the data took six weeks from data acquisition to the first draft of the respective maps. It was necessary to prepare two different data sets with the first data set prepared for the distributive flow map. The primary focus was the distribution flow map that required a unique arrangement of data to properly function within the specialized ArcMap tool. The data phases are highlighted in Table 4, which indicate the sequential nature of the map creation process.

Table 4. Phase Two Data and Map Preparation

Task	Phase 1	Phase 2	Phase 3
Data	Sorting and data preparation for Flow distribution models and Dot Density Maps	Finalize coordinate tables and creation of Population tables	
Distribution Flow Map		Edit and finalize end point coordinates	Import, to ArcGIS Story Map, Create and edit map
Dot Density Map		Import to ArcGis	Create Edit and Finalize Map

3.3.3.3. Map Creation

The data preparation proved to be the most challenging aspect to the creation of the maps, primarily due to the special requirements of the ArcMap tools and their respective calculations.

Several attempts were made trying to create the Distributive Flow map with the

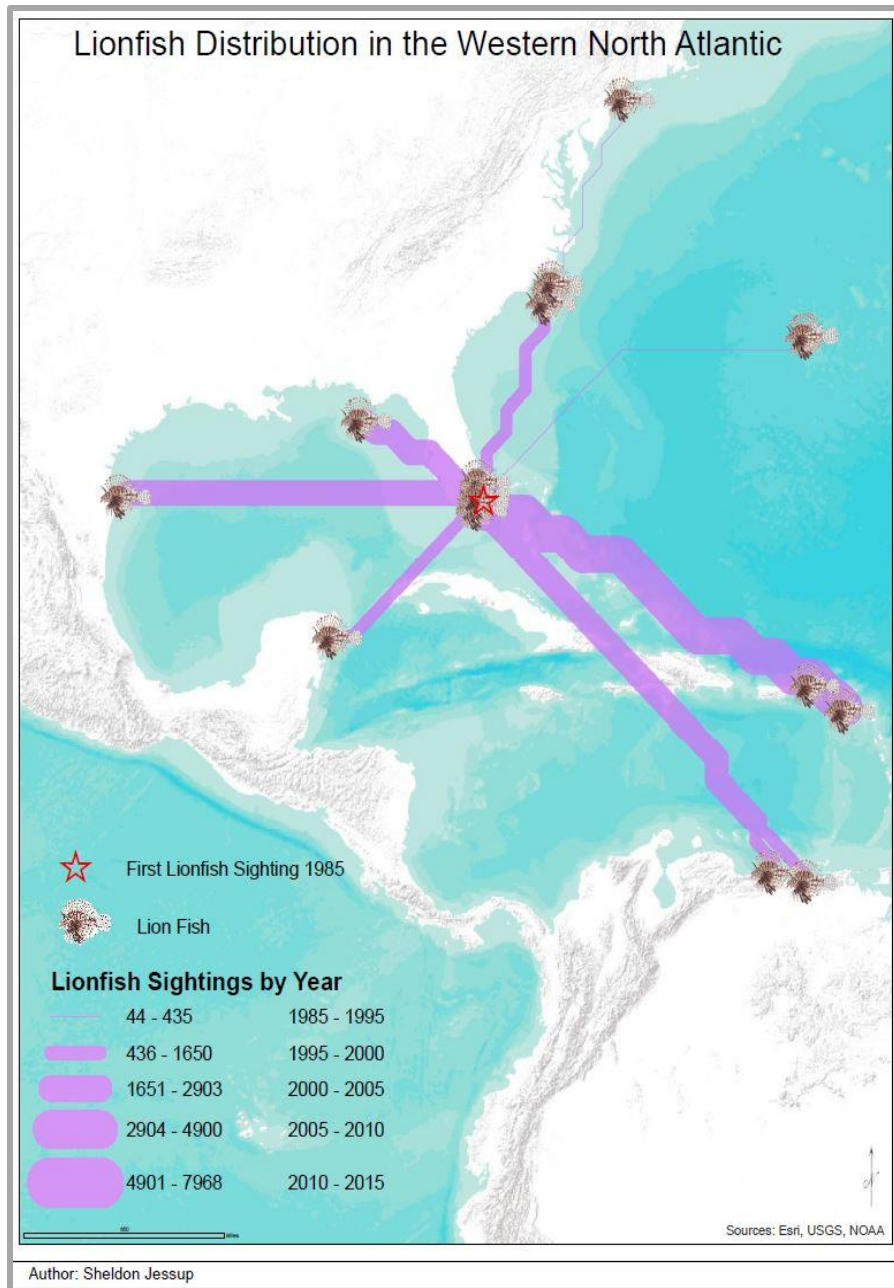


Figure 9. Distributive Flow Map of the Lionfish Population

FlowMapGenerator, that required frequent restructuring of the data for the ArcMap tool to calculate the data properly. The primary error was the need to separate the origination point into its own table. Once all the primary data preparations were properly in place map creation was successful. This allowed for two weeks for proper map cartography.

Data preparation proved effective with the creation of these three maps. The primary Distributive Flow map created with FlowMapGenerator within the ArcMap toolbox does mimic the idolized maps from Charles Minard. (Figure 3) The data preparation also proved successful when capitalizing on the ArcMap standard tool kit to create the Population Dot Density Map (Figure 11). The Symbology tab located within the layer properties offers the Dot Density selection option which created the look needed for the project (Figure 10). The Coral Reef map

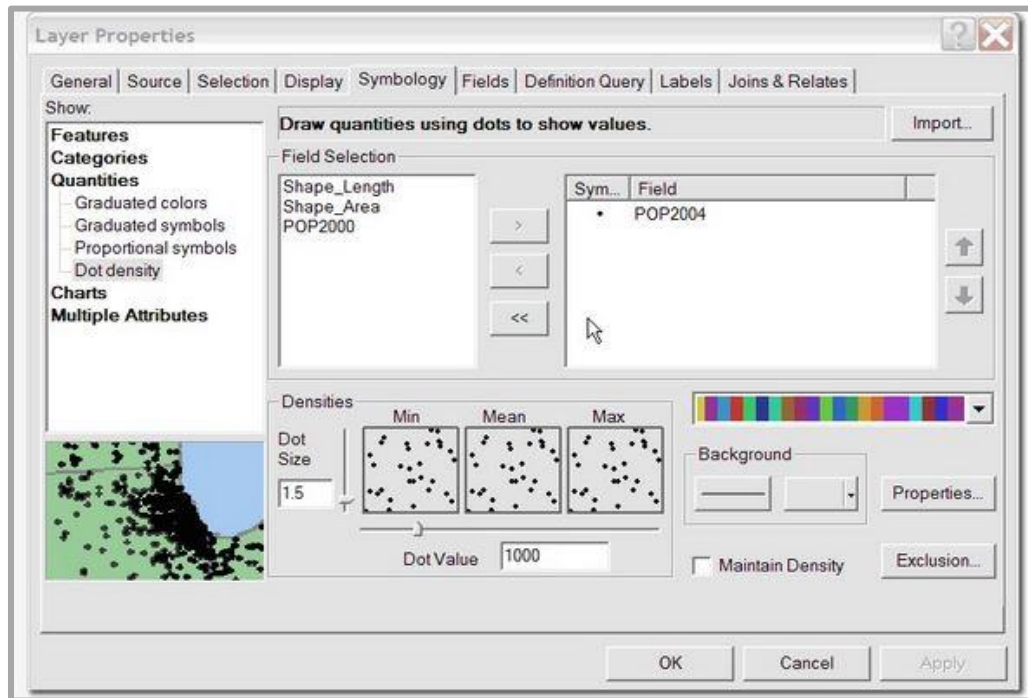


Figure 10. Layer Properties

data was imported into ArcMap and the corresponding reef coordinates were layered on top of a Esri provided base map.

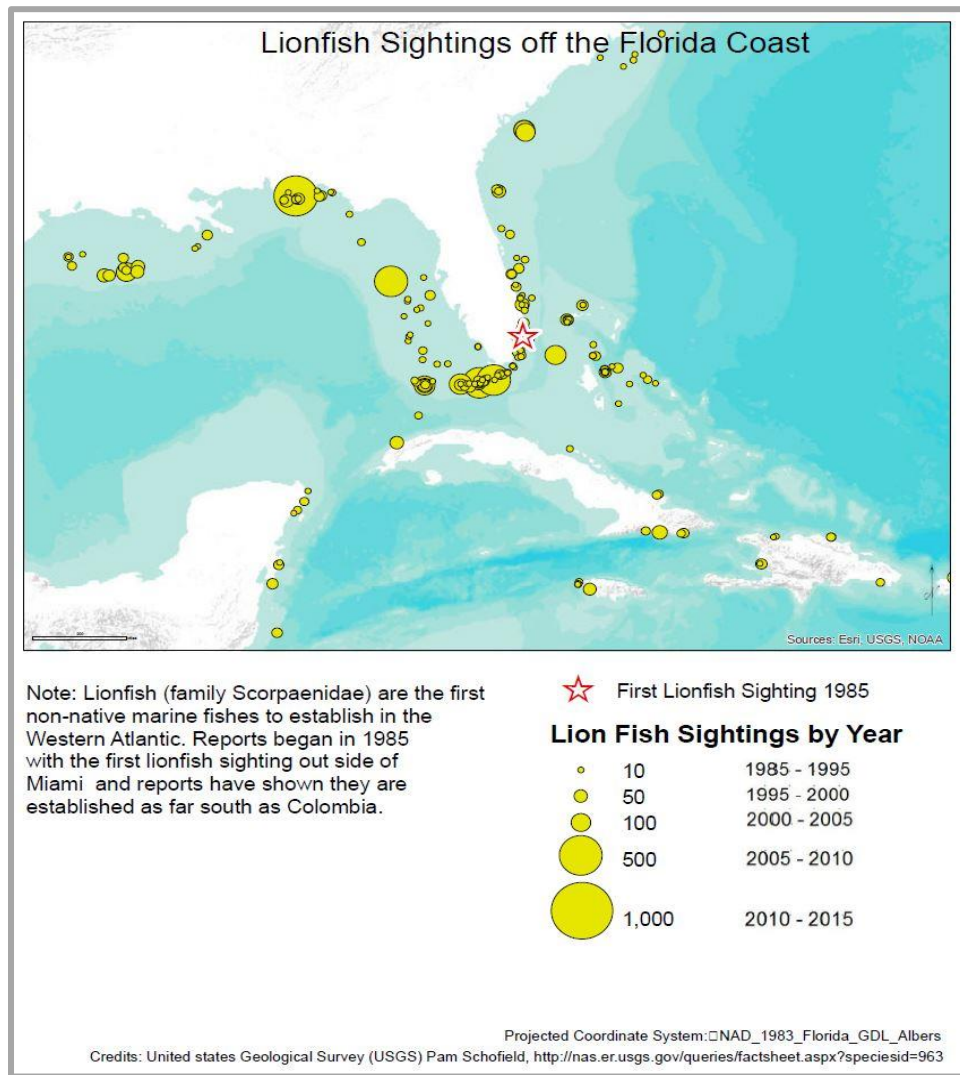


Figure 11. Population Dot Density Map

3.4. Integration of Mixed Media within the GIS Story Map

The development of the GIS components of this project were done simultaneously between ArcMap 10.4 and ArcGIS Online. The technology challenges and limitations of working with two platforms simultaneously will be discussed further in this chapter. This section deals specifically with the media selection, with the appropriate Story Map purpose, and the final

maps used to tell the lionfish narrative. This section provides insight to the mixed media selection and final integration within the Story Map.

3.4.1. Story Map- Media Selection and Integration

During the preliminary photo acquisition period, photo searches were performed using online search engines. Based off of search results and quality of the images, images were saved and ranked off by quality of the individual image. Final filtering of images for this project were restricted to public images except photographs from Antonio Busiello. A rating of one to five stars was given to the picture, with five stars being the highest, and only the highest rated images were utilized for this project. Images that illustrated the lionfish being fed by spearfisherman to native predators such as sharks and groupers were taken by photographer Antonio Busiello, and with his written authorization were utilized for this project. The photos Busiello captured truly highlight the lionfish invasion in their natural reef environment and warranted the extra effort in acquiring authorization necessary.

Photos utilized within this project were saved using the online photo repository Flickr. Flickr allows ArcMap Online to freely display images without the need to store large file sized photos on their Esri servers (Esri 2017). Flickr provides a URL link that was easily imbedded into the Story Map template to display the images throughout the Story Map. Table 5 provides a detailed account of all the photography media utilized for this project and highlights the purpose for each photo within the lionfish narrative.

Table 5. Media used

Photograph Used	Terms of Use	Project Purpose
ORA- Macro Coral Image	Public image with watermark	Macro photograph of a Small Polyp Stony coral

Large Grouper	Public image with watermark	To highlight natural predators of lionfish
Dissected lionfish	Public image with watermark	To highlight the voracious appetites of the lionfish
“biting off more than he can chew” lionfish	Public image with watermark	To highlight the voracious appetites of the lionfish
Graph of lionfish temperature	Public record	Overview of the adaptive nature of the lionfish
Speared lionfish	By permission from Antonio Busiello	To highlight ongoing efforts to create a taste for lionfish

3.4.2. Story Map- Map Integration

ArcMap 10.4 was the primary platform used to develop the maps used in the Story Map. To properly utilize the Story Map software, the maps were created on ArcMap 10.4 and then reconstructed in ArcMap Online to be linked later to the Story Map. Due to the integration of ArcMap 10.4 and ArcMap Online, data was easily transferred between the two platforms. The process of transferring each of the maps created in ArcMap 10.4 to ArcMap Online included sharing of the map’s metadata (descriptions, keywords, features) and analyzing the map for possible errors. In order to recreate ArcMap 10.4 maps in ArcGIS Online, a file or map export was necessary from ArcMap 10.4. All of the maps were exported from ArcMap 10.4 to a .zip file stored on to the computer’s hard drive which was then uploaded to ArcMap Online. Some of the maps were easily imported to ArcMap Online, however, this import method was only ideal for maps that contained less than 1000 features. The attempts to import a zip file containing more than 1000 features generated a system error indicting the file was too large for a successful import to ArcMap Online.

This restriction of one thousand records was perplexing as the Population Density map (Figure 11) contained over five thousand records. After searching the Esri online support forums

I could not find the resolution. In the Esri support forums, there is a section to *ask a question*. I posted my question on how to import over 5000 records into ArcMap online. Esri support suggested breaking up the data into segments less than one thousand features. The Population Dot Density map (Figure 11) was fragmented into each individual year, which then allowed the import of data into ArcMap Online as each year by itself was less than one thousand features. The separation of the data proved beneficial as this provided nineteen clickable links by year to immerse the user further within the interactive maps. Once all the maps were recreated in ArcMap Online map, integration to the lionfish narrative followed.

The distinct components of the distributive flow map lead to it being placed on the home page of the Story Map. The distributive flow map (Figure 9) best illustrates the vast spread of the lionfish population throughout the Western Atlantic. Using lines of different widths will immediately inform the user of the higher distribution of the lionfish populations. The next map utilized best informs the user of what is at threat. The Coral Reef map highlights the location of where all the reported coral reefs within the Western Atlantic and Caribbean (Figure 15). Shortly following the coral reef coordinate map is a map created to highlight the difference between the lionfish's natural habitat in the Indo-Pacific versus the Western Atlantic. The Coral Reef Area Map was developed to help highlight the dramatic difference between the Indo-Pacific (Figure 16) in abundance of coral reefs per square kilometer compared to the coral reef area of the Western Atlantic (Figure 17). Each map integrated within the Story Map fluidly developed the lionfish narrative, their purposes are labeled in Table 3.

3.4.3. Story Map- Video Integration

The videos used within the Story Map were public videos also created to help inform the public about the lionfish invasion. The public nature of the videos found on YouTube allowed

for flexibility of integration within this project. Similar to the integration of the image media used, YouTube provides a specific URL that can be imbedded into the Story Map template. Once the URL has been saved within the Story Map, the opening image of the YouTube video is visible and specific settings can be leveraged for the best immersion of the viewer. The primary settings utilized for this project were to begin the video upon user clicking on the *play* button. A secondary option of beginning the video automatically proved to distract the user from the narrative within the scrolling column. Allowing the user to play the video when they were ready proved to be the appropriate setting for this project. Three specific videos were implemented into the Story Map. These videos each helped bring home a specific narrative purpose within the Story Map. Table 6 illustrates the different videos with their intended purpose within the lionfish narrative.

Table 6. Videos used

Video Used	Terms of Use	Project Purpose
Stay Away from Packs of Lionfish	Public video	Overview of the unique nature of lionfish hunting as a pack
How Florida is handling invasive lionfish	Public video	Detailed account of a lionfish derby
Hello Ocean: Invasive Lionfish Hunt in St. Barth's	Public video	Detailed account of a lionfish hunt

3.4.4. Integration of all Mixed Media Components

The mixed media components of the Story Map included maps, images (macro, photos from the community, and photos from the web), and videos. Each media type had its own unique integration method, whether it was imbedding a URL or simply linking a map from ArcMap Online. During the project cycle, the project outline carefully looked through each piece of the Story Map and the narrative was finalized along with the media utilized. Each media type was

instrumental in capturing the impact of the lionfish invasion. The final project utilized twenty-four maps, eight images and three videos. Table 7 shows the mixed media integration within the lionfish Story Map. These materials were integrated to fully tell the lionfish invasion story and keep the user engaged. Upon completion, the Story Map was then referenced against the project outline. The Story Map was published publicly in June of 2017.

Table 7. Story Map Narrative Content

Section Title	Description	Media Utilized
Invasive Lionfish threaten our native Western Atlantic Reef environment	Introduce the lionfish invasion in the Western Atlantic	Interactive map – Distributive flow map
Our Coral Reefs	Introduce Corals at threat	Inter active map of the coordinate data on the worlds reefs, zoomed into the Western Atlantic
Coral Are Sedentary Animals	Describes the coral reef and the function they serve in the world’s oceans	Macro image of a small polyp stony coral
Why are lionfish not decimating Indo Pacific? Interactive link to jump the viewer into a zoomed in map of the Western Atlantic Image of large grouper	Explain the natural predators found in the Indo-Pacific that keep lionfish populations in check	Interactive map of the world’s reefs highlighted by the sqkm of total reef area
Why do lionfish pose a formidable threat? Image of lionfish with another a fish stuck in his mouth	Highlighting the predatory appetite of the lionfish	An image of a dissected lionfish with 30 smaller fish in the gut
Wild cats of the ocean	Highlighting the unique hunting style of the lionfish	A YouTube video highlighting the unique hunting strategies lionfish use
Interactive Lionfish population maps with hyperlinks from 1985-2015	Allow the user to engage with the Story Map by clicking on interactive links per year	A chronological series of maps highlighting the population growth since 1985

Warming Atlantic May invite lionfish to Deeper waters to breed	Highlights the possible effects of climate change and the lionfish's ability to adapt to water temperature	Line graph and bar chart also illustrating the lionfish population growths
What can you do	Emphases what the average viewer can do to contribute to help with the lionfish invasion	YouTube video highlighting what Florida is doing to control the lionfish populations
Creating a taste for Lionfish	Explanation of eating lionfish	High definition image of a spear fisherman catching a lionfish
Feeding the Sharks and Barracuda	Possible creation of creating natural predators to the lionfish	High definition image of a Spear fisherman feeding speared lionfish to a shark
Getting Everyone and Anyone involved in protecting our Oceans Resources Imbedded within text: Link to another YouTube video by National geographic which labels the lionfish invasion as the "perfect storm"	Highlighting that lionfish hunts are limited to scuba regulation depths	YouTube video of a lionfish hunt
Ready to Get involved?	A website where the citizen can purchase lionfish	Pre-loaded webpage of reefsavers.com a place where everyone can contribute to the "weeding of the garden"

Chapter 4 Results and Revisions

This chapter describes the revision process of the Story Map. This section relates the major revisions throughout the Story Map building process. Feedback was provided in three phases throughout the Story Map building process. Principally feedback was given from a small group of volunteers who were selected for their lack of familiarity with the invasive lionfish. When ready, the story map was shared with a lionfish subject matter expert, Dr. Pam Schofield. Lastly, the Story Map was shared among a larger group of volunteers with a brief survey to capture a sample size of the effectiveness of the Story Map. The next few sections provide an insight to the feedback given and the ensuing revisions on narrative, maps and media utilized within the Story Map.

4.1. Story Board

Since the commencement of this project a small group of volunteers were instrumental in guiding the narrative of the Story Map. The small group of volunteers provided guidance in template selection, to media collection and cartography edits. The constant feedback provided by the small group of volunteers ensured a constant progression in the development of the Story Map. The purpose of this case study through the Story Map is to inspire and motivate the lay citizen to contribute to the solution of the lionfish invasion; the volunteers helped keep the narrative focused and on track.

The distribution map was suggested by the volunteers to be the landing page, or the first page the user sees upon opening the Story Map. Opening with the Distribution Flow Map provided the highest impact according to the small group of volunteers. The purpose of beginning with the distribution map is to allow users to visualize the spatial extent of the geographical area in which we are discussing throughout the lionfish narrative (Figure 12). The

following maps and media were also finalized on the story board, which formed an outline for the Story Map. Throughout the span of three months the continuous referencing of the original story board and weekly ongoing feedback from the small group of volunteers provided Story Map revisions that allowed for the project’s completion in the predetermined time limit.

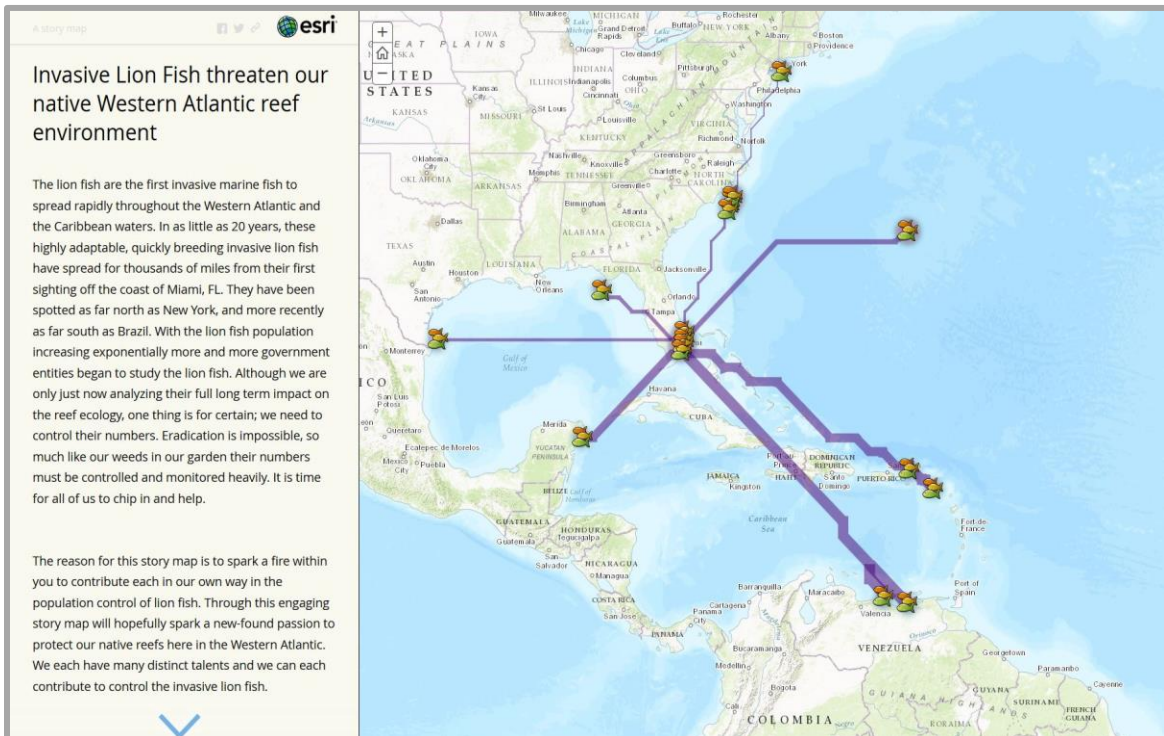


Figure 12. Opening of the Lionfish Story map

4.2. Story Map Expert Feedback

The second objective upon the completion of the Story Map was to receive feedback from a lionfish subject matter expert. Dr. Pam Schofield whom provided the data for this project and was open to providing feedback for the completed Story Map. When presenting the Story Map to Dr. Schofield, there was no predetermined questions to provide specific feedback, but rather the topic was left open to receive any type of feedback. The URL for the completed Story Map that was shared with each of the volunteers was:

<https://uscssi.maps.arcgis.com/apps/MapJournal/index.html?appid=3583b1138cc44c13b2c035cf>

[fd8d9e14](https://docs.google.com/spreadsheets/d/1yjDqb3Md5Weq6NKWHrC1FejyfmLcFkFUcAkKuJS) This link was followed by set instruction to fill out a participant survey with the URL: <https://docs.google.com/spreadsheets/d/1yjDqb3Md5Weq6NKWHrC1FejyfmLcFkFUcAkKuJS> [ToTc/edit?usp=sharing](#) The feedback from the general public was also deemed highly valuable as one of the goals of this project was to generate wide-spread awareness of the severity of reef destruction. This survey falls under the exempt category for IRB approval and was submitted to the USC Office for the Protection of Research Subjects.

This project was Dr. Schofield's first Story Map and was received with great enthusiasm. Dr. Schofield provided positive feedback on the lionfish narrative, commending the maps and the narrative flow. Dr. Schofield highlighted a few grammatical errors which were quickly corrected. However, the constructive criticism Dr. Schofield provided was regarding the controversial topic of feeding the native Western Atlantic predators (Figure 13). Dr. Schofield suggested that this topic should not be encouraged as it is highly debatable and has not provided any tangible data in favor of feeding the native apex predators.

As widespread as the lionfish are throughout the Western Atlantic, the native apex predators have not yet developed a taste for these invasive fish. A current strategy, not supported by any government agencies, is to spear the lionfish, then feed them to native predators in the surrounding area. The concept, or the hope, is to help the native apex predators to develop a taste for lionfish. Sharks, groupers and barracuda can safely consume the lionfish despite the venomous spines. This philosophy is mostly spear-headed by local divers and fisherman in the local communities who have been greatly impacted by the lionfish invasion. The hopes are if the native predators eventually see the them as prey, these local apex predators will control the lionfish population and the ecosystem will eventually find its natural balance. However, there is limited evidence that the apex predators like sharks will consume the lionfish without human

intervention (Schofield 2017). Dr. Schofield’s concern on advertising the highly controversial topic of feeding the local predators was implemented in the final version of the Story Map. In Figure 14, the introductory paragraph which opens with “Creating a Taste for Lionfish” was edited to reflect Scofield’s feedback. This screen was edited to not only reflect the controversial nature of this topic, but also to highlight the local divers and fisherman who are spear heading

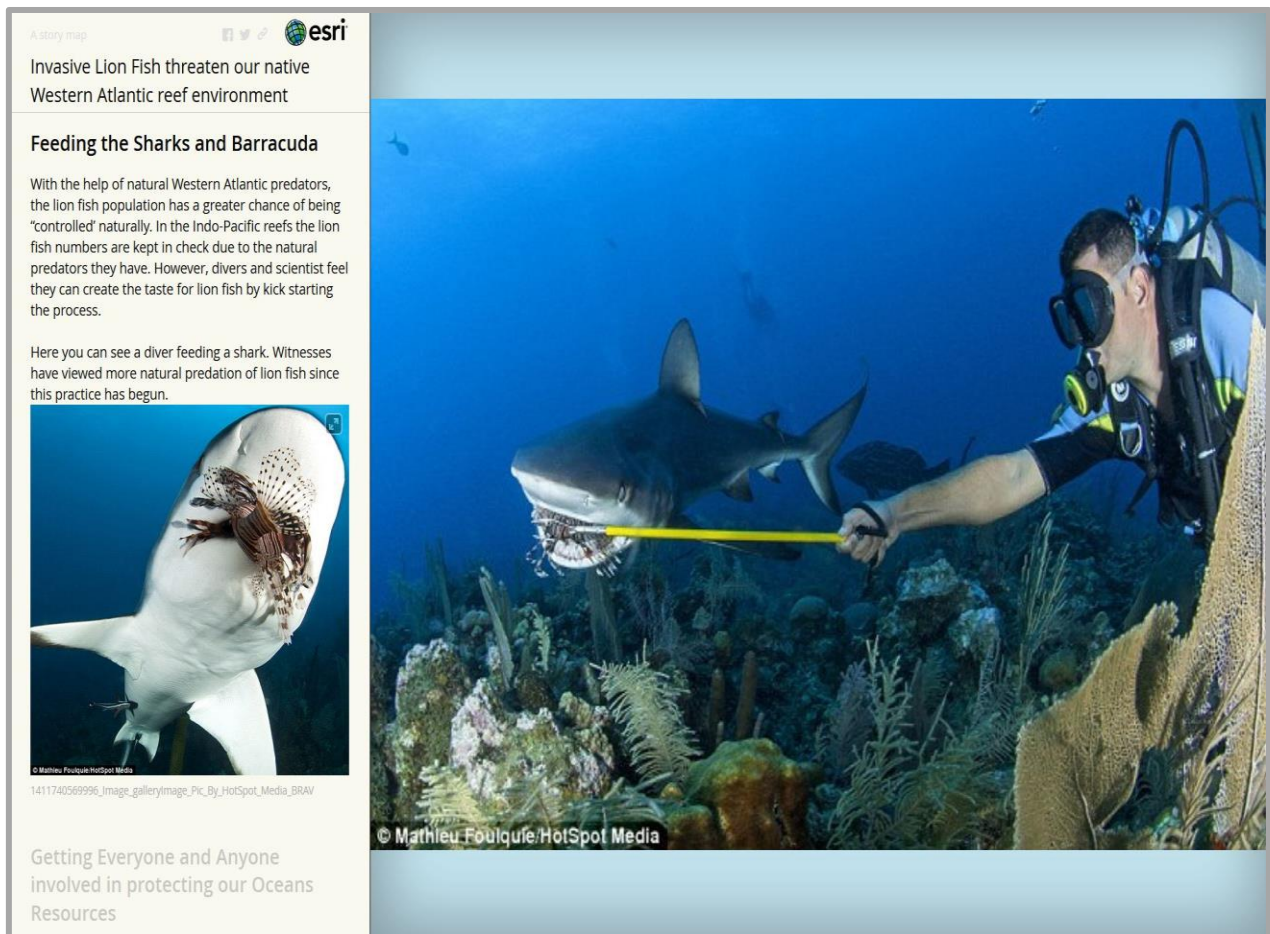


Figure 13. Highly Controversial lionfish being fed to a native Atlantic Shark

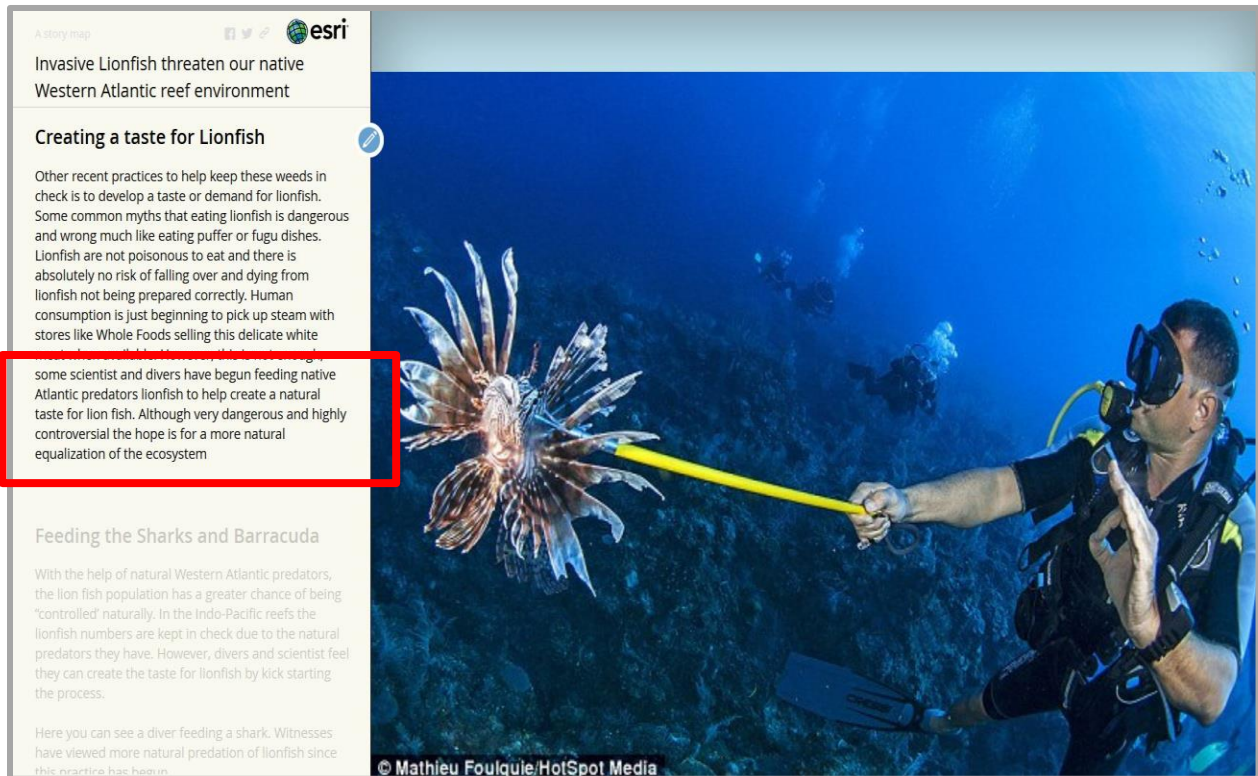


Figure 14. Updated Story Map Page

this notion. Figure 14 highlights the edit with a red box to indicate the final changes regarding the controversial topic. This, provided a clear view of the controversial nature of this topic.

Although the concept of spearing a lionfish and feeding it to native apex predators is very controversial the passionate people behind this idea of creating a natural taste for lionfish among the native apex predators feel that it has been fruitful. This passion, this conviction, is shown on the public videos within the Story Map. However, some scientists like Dr. Schofield feel that hand feeding the sharks could lead to a rise in shark attacks as they may also assume the connection of food to humans as the humans are hand feeding the lionfish to them. Lastly, it is important to mention that this technique is highly dangerous and should not be attempted.

4.3. Map Results

The data preparation proved successful with the map results completed and integrated into the Story Map. The landing page of the distributive flow maps helps draw the viewer in. The coral reefs and the entire ecosystem that revolves around the reefs could be at risk too. To help illustrate the area under threat the Coral Reef maps with the coordinated data helped highlight the coral reef, and the coral reef area. Specifically, the Western Atlantic and the Indo-Pacific coral reefs. The Map in Figure 15 is the coordinated data, or the locations of all the reported coral reefs. Based off the same coordinates polygons illustrate the total coral reef area, in SqKM shown in Figure 16. Figure 17 was used to highlight the vast area of coral reefs compared to the



Figure 15. Coral Reef Coordinate Map

limited amount of coral reef area within the Western Atlantic. Figure 17 emphasizes the reefs from Florida down to Puerto Rico have the highest concentration of coral reef, also, with the highest population of invasive lionfish who prey on the coral reef fish. With these map results integrated within the lionfish narrative we can now begin to seek feedback on our narrative.

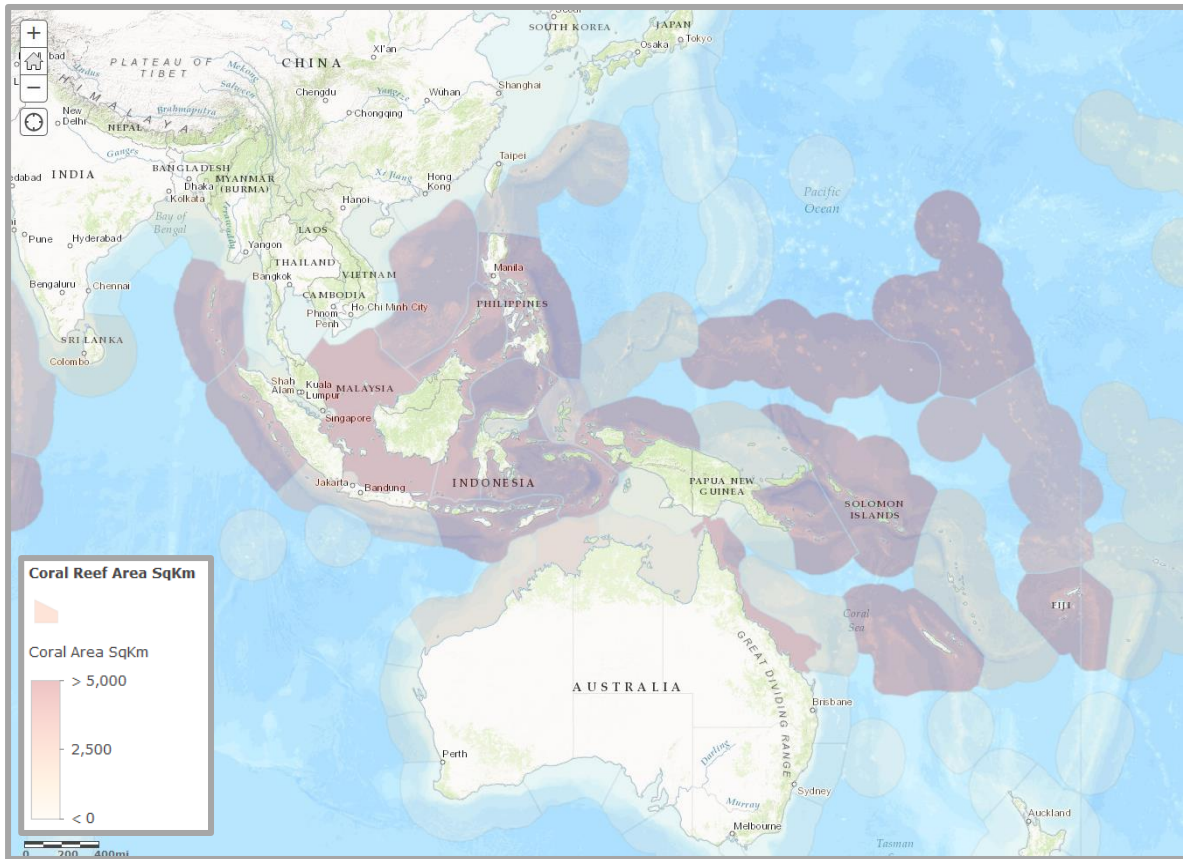


Figure 16. Indo-Pacific Coral Reef Area Map

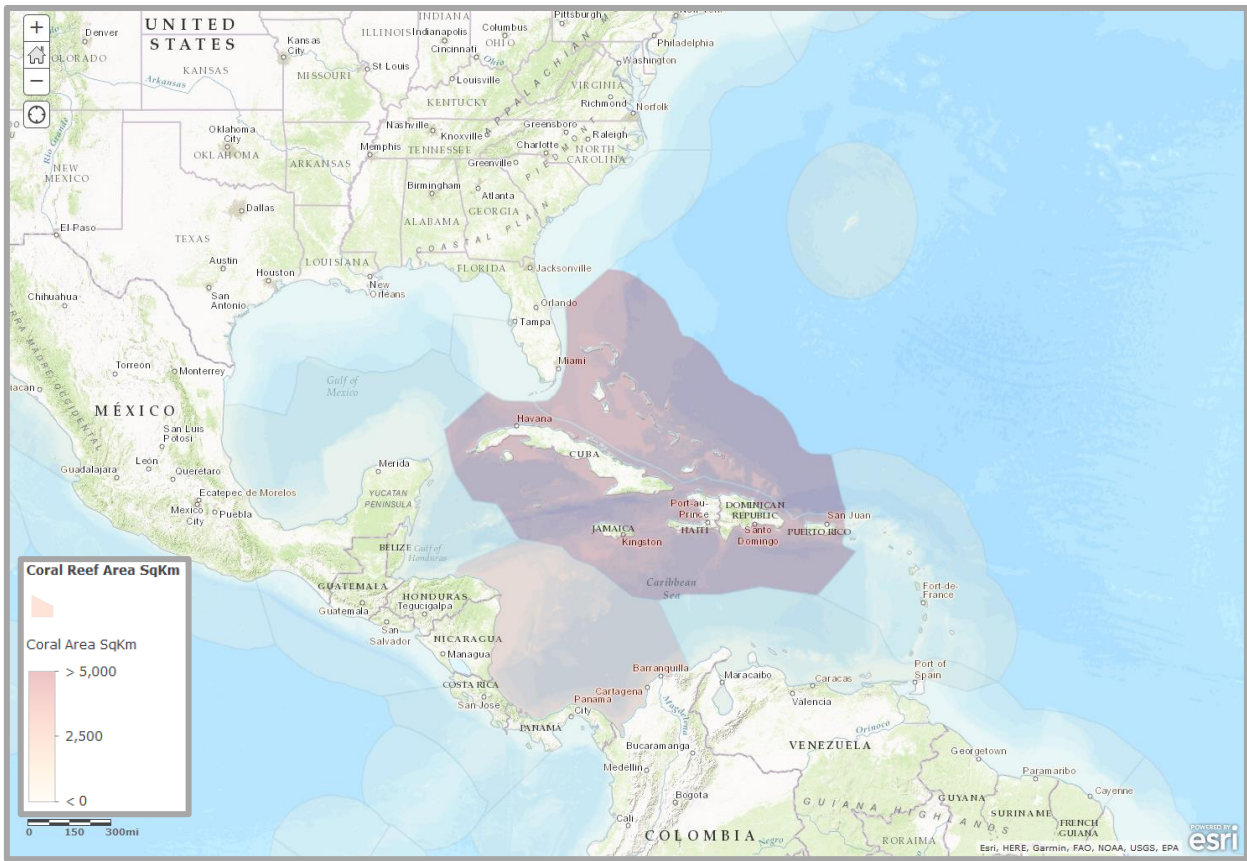


Figure 17. Western Atlantic Coral Reef Area Map

4.4. Story Map public feedback

With the completion of the Story Map reviewed by an industry expert it was time to receive feedback from the lay people that may not be aware of the invasive nature of the lionfish. The Story Map was made public and this link of the Story Map was shared between a larger group of volunteers with a short three question survey required to be answered upon completing the Story Map. The sample size consisted of 20 volunteers however, only 17 responded to the survey questions.

4.4.1. Case Study Survey Results

To determine the effectiveness of this case study's Story Map a survey was used to measure the results. The survey was created on Google Sheets with the intention of providing a

central location for all the responses. Each email to a volunteer contained the link to the Story Map with the request to fill out the survey upon completing their individual review of the Story Map. The survey was a Google Doc stored on a public drive that allowed the respondent to enter in their answers. It is important to note that all volunteers who reviewed this Story Map are from West Texas and do not reside near the Western Atlantic waters.

The survey consisted of three questions. The objective of the survey was to understand the user's thought process upon initially reading the subject matter and then completing the Story Map. The first question stated; "Did you know about the lionfish invasion prior to viewing this Story Map?" This yes or no question was intended to understand if the volunteer's prior knowledge of the lionfish invasion would possibly determine the type of feedback given. In

fx		A	B	C	D	E	F
1	Survey questions		Please Circle one				
2	1. Did you know about the Lionfish invasion prior to viewing this Story Map?	Yes	No				
3							
4	2 Did you think at the beginning of the Story Map you would be able to contribute to the solution	1	2	3	4	5	
5							
6	3 Did you think at the end of the Story Map you would be able to contribute to the solution?	1	2	3	4	5	
7							

Figure 18. Survey used for larger group of Volunteers

order to produce the chart in Figure 19, a value of 1 was given to the response “yes” and a zero value was given to all the “no” responses.

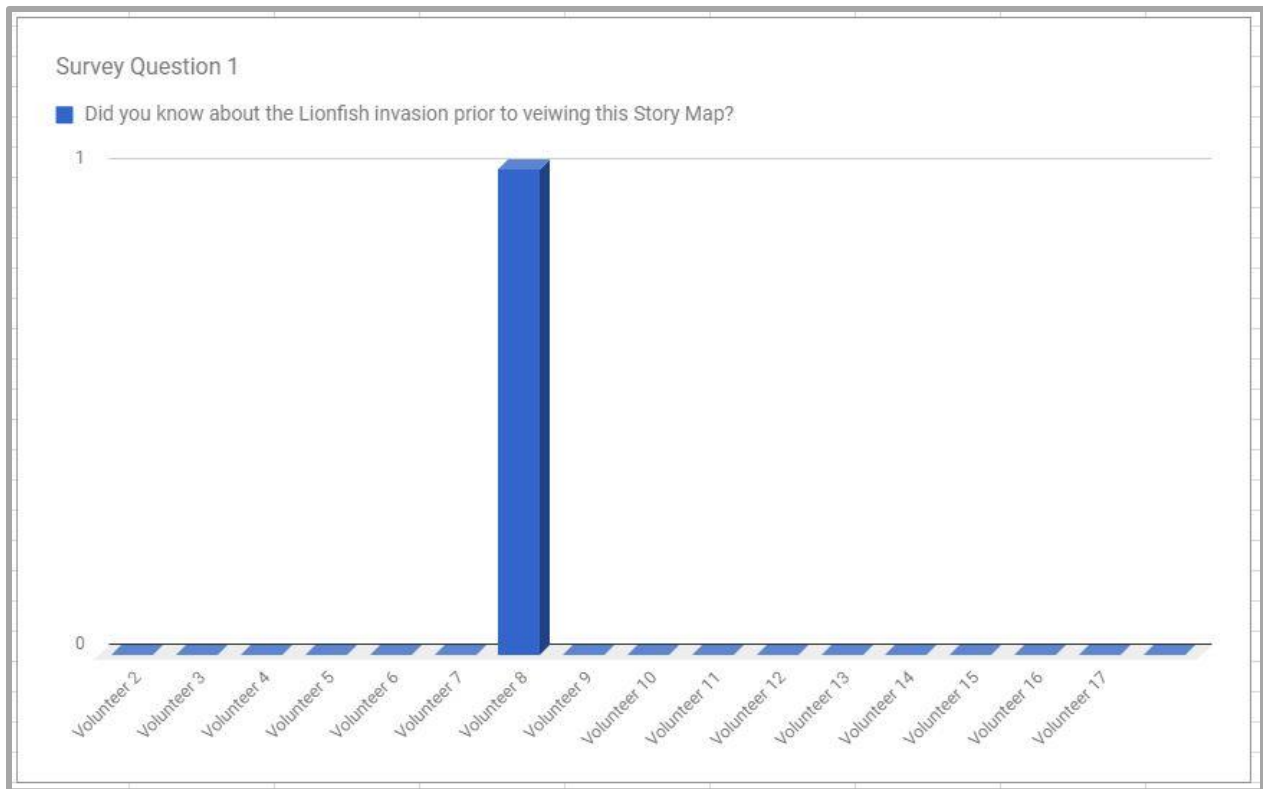


Figure 19. The first survey question

The following two questions were rated on a sliding scale from one to five. With five carrying the most weight, it was explained that a response of one meant the viewer absolutely did not think they could help contribute to the invasion lionfish solution. Contrastingly a response of five meant they felt confident in their possible individual aid to the solution of the invasive lionfish.

Seventeen total surveys were completed in a timely matter among the large volunteer group, although a sample size of twenty was desired. Figure 19 indicates that only one person in

seventeen was aware of the lionfish invasion. This continues to support the hypothesis that many lay citizens are unaware of the invasive lionfish in our Western Atlantic waters.

The following question was designed to gauge how the viewer felt at the beginning of the Story Map and upon completion. The question posed, “Did you think at the beginning of the Story Map you would be able to contribute to the solution?” was asked upon completion of the first introductory landing page. The results of this question are in Figure 20.

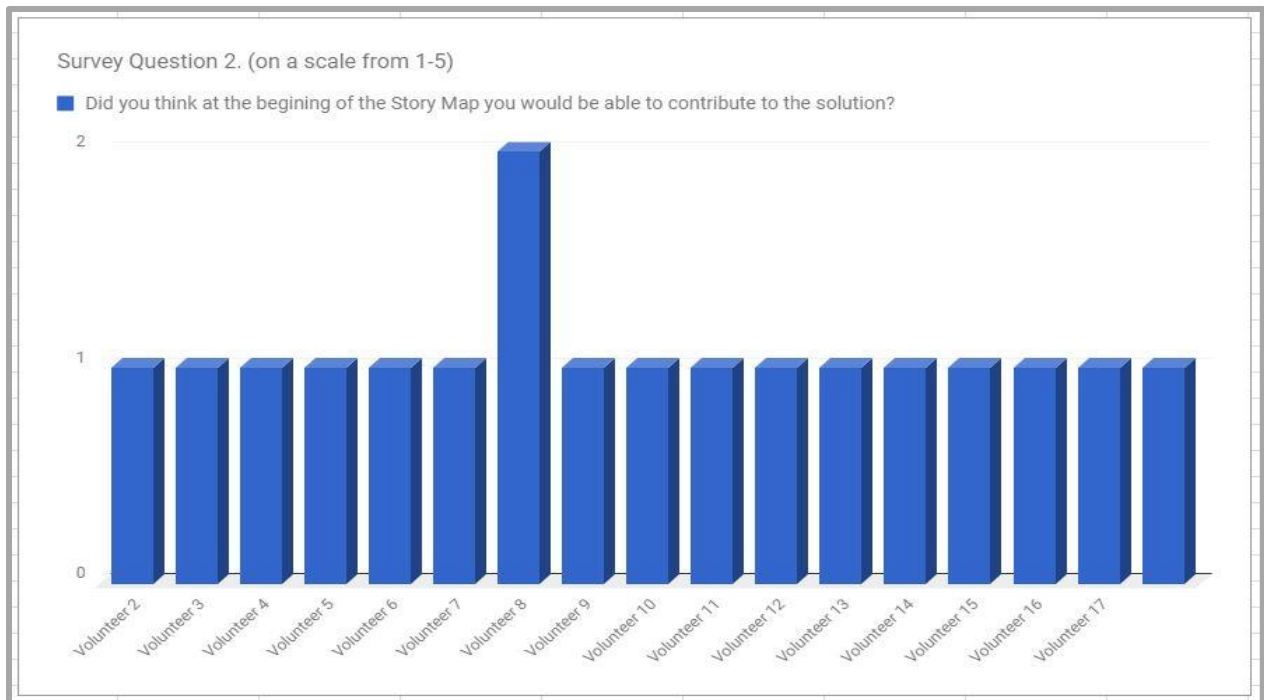


Figure 20. Survey Question

Similarly, to the first question most of the respondents felt as though they could not contribute to the solution of the invasive lionfish. Volunteer 8 who is shown selecting a number two indicated that she felt as though she could contribute at the beginning due to her saltwater aquarium hobby. Volunteer 8 had previously kept lionfish in an aquarium enjoying their majestic nature in her living room.

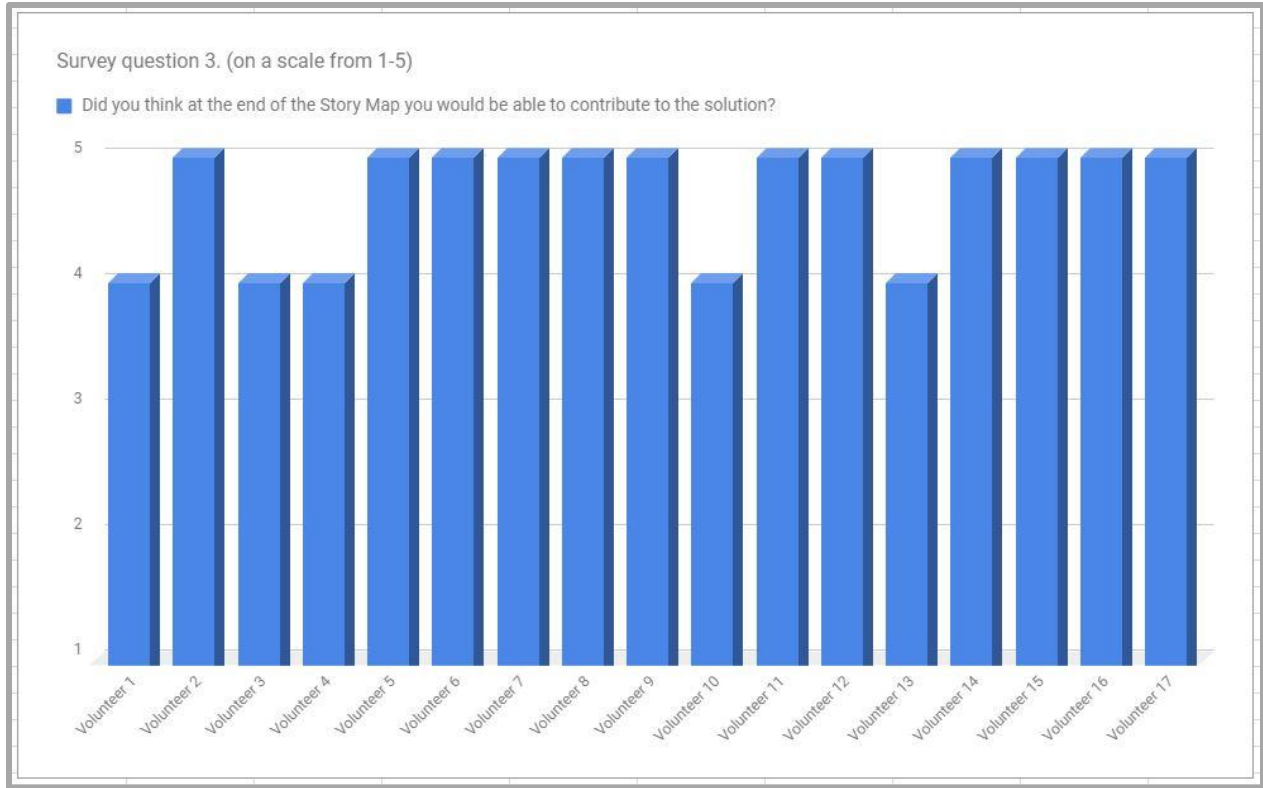


Figure 21. Final Survey Question

The last survey question was designed to capture the feeling of the viewer upon completion of the Story Map (Figure 21). With a similar ranking of one to five, and the results are also very impressive. Four of the seventeen responded with a four, and the rest of the survey population felt 100% confident in their ability to contribute in some fashion to the lionfish invasion by responding with a solid five.

The small sample size of lay citizens viewing the Story Map proved to be a positive start in sharing this Story Map with the public. This case study proves the Story Map is effective at increasing awareness among the lay citizen. Most people are still unaware of the lionfish invasion and this Story Map can provide options for those community members to contribute to the solution.

Chapter 5 Discussions and Conclusions

Drawing from the success of the feedback and surveys provided by respondents, the lionfish case study was successful in raising awareness for this small sample size. However, further revisions and refinement of the Story Map may be more useful in encouraging dialogue about the invasive species. This chapter examines a few considerations on revising the Story Map. First, the effectiveness of the Story Map technology as an online GIS tool to educate and inform local communities. Secondly, the Story Map as a delivery platform to bridge the gap between subject matter experts and the lay citizen. Lastly, the relevancy of this technology to provide an ongoing awareness of the lionfish invasion.

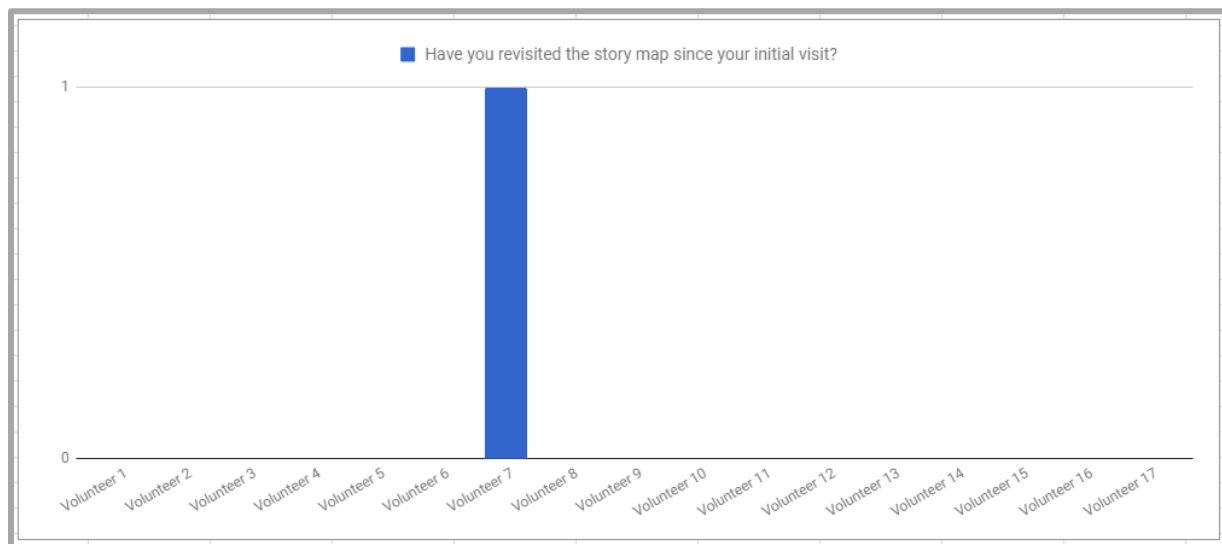


Figure 22. Poll asking initial users if they have revisited the Story Map

5.1. Story Map Effectiveness

The overall goal of selecting the Story Map in this case study as a method of increasing public awareness regarding the invasion lionfish was moderately successful within our small sample size. Further research on a larger sample size and longer research timeline would provide

better data for more conclusive results. The small sample size still provides us with the conclusion that the Story Map was successful in informing the viewers of the invasive lionfish on their principle viewing.

The Esri Story Map narrative was successful in raising awareness to our small sample size, however the results of the case study showed the Story Map was only effective for a single use. Although impactful upon first sight, the Story Map technology did not bring people back to revisit. Perhaps this could be due to the subject matter not being of interest, however, the goal of this Story Map was to raise awareness among the lay citizens. The immediate result of heightened awareness was tangible through the brief surveys the volunteers provided upon completing the Story Map. However, when the Story Map was consumed on a single visit most of the volunteers did not revisit the Story Map. In fact, of the seventeen who participated in the overall Story Map survey, only one had revisited the Story Map when polled fourteen days later. In Figure 22 a value of 1 was given to the only respondent who had responded positively for revisiting the Story Map.

The goal of this case study was to increase awareness of the lionfish invasion and to that fact it can be concluded that it was temporarily successful. Most of the small sample size were not aware of the lionfish invasion and now have been informed of the subject matter. However, the distribution of the Story Map will have to be ongoing and continuous for long term results that would encourage users to revisit the Story Map over a longer period. The results provide us with the insight that a Story Map must not be a single use case, rather an ongoing project that would encourage frequent updates to continue to increase awareness among the community. Perhaps the use of social media could help with the continued interest and visitation of the story map.

5.2. Bridging the Gap

Research of invasive marine species requires many subject matter experts with different backgrounds, typically from many different organizations. The use of a Story Map as a method of delivery of their research to community in a digestible format proved to be successful in the engagement of the community. Although in this case study did not involve many different subject matter experts or organizations, the Story Map as a platform, proved successful as a delivery format to combine the knowledge of all the experts involved. The distribution of knowledge is vital to involving the community, however the information disseminated must also be digestible and not overwhelm those who are not knowledgeable in the subject. The Story Map proved successful in providing digestible content to the user in a platform they can consume at their own pace. Furthermore, the Story Map was easily accessible on many different platforms. Some of those surveyed accessed the Story Map from a mobile device or tablet. Although those surveyed did not answer a question regarding the platform in which they accessed the Story Map, the flexibility of the Story Map to be consumed by the public through any means provides a platform for any project.

The target audience for this Story Map was they lay citizen who are unaware of the lionfish invasion and the goal was to increase awareness. The Story Map proved to be an asset in accomplishing this goal. The Story Map can be developed to target all subject matter experts. The reassessment of the Story Map's target audience can possibly increase awareness of the Story Map as a tool among subject matter experts to deliver the results of their studies.

This case study proved that a Story Map can properly disseminate information from the subject matter experts to the lay citizens of a community. This study proved the potential of the Story Map to inform and inspire the local community to act. However, the only improvements I

would make would be a way to trickle the information with a small steady stream of information, so that the viewers will continue to return to the Story Map. The survey results indicated only 1 of the 17 volunteers returned to the Story Map after viewing it the first time. This small but potent detail is what drives social media, small frequent visits.

5.3. Conclusion and Ongoing Awareness of the Lionfish Invasion

The use of a Story Map is highly adaptable and can be customized to local communities affected by the lionfish invasion. The lionfish invasion has already spanned as far north as New Jersey and as far south as Brazil. Dr. Schofield refers to lionfish as weeds in our garden. This perfectly surmises the situation with the lionfish. They are permanently part of our coral gardens and need to be plucked from the garden to let the native wildlife thrive. Although eradication is impossible, it is possible to control their populations in the coral reefs. Lionfish have proved themselves as being adaptable to many temperatures and depths, and more communities are educating the public through various means. This case study proves that a Story Map is an effective tool to increase the public awareness in the different communities. The Story Map, with ongoing changes to inspire revisits by the public, can continue to increase the overarching reach within the respective communities.

The lionfish was the first marine invasive species in the Western Atlantic and has been studied since the late 1980's, however not many people know of the full impact of the invasion. The lionfish consume native fish populations, and a comprehensive study of the impact of the lionfish on the native reef fish has yet to be published. In fact, the full impact of their presence has yet to be determined, as the scope of the research project proves to be too challenging to conduct.

Future use of a Story Map could help deliver the results of any new research carried out on the lionfish or native reef fish. For example, a localized study on measuring the impact of the controversial topic of feeding speared lionfish to sharks and other apex predators. Whether this method proves to provide some natural ecological relief with the lionfish invasion has yet to be determined. With the lionfish impacting different communities surrounding the Western Atlantic, the Story Map is a viable vehicle in which to disseminate the research results to the local communities.

By increasing the consciousness of a community in West Texas, the goal to increase community awareness was accomplished. This research project has shown is the power of a Story Map to disseminate information to the public. When the user of the Story Map has a vested interest in the subject of the Story Map they will become part of the solution. It is vital that the subject matter experts do not keep their research results among themselves; the use of the Story Map can properly deliver impactful research results and increase public engagement. The knowledge gap between the subject matter experts and the lay citizen can be easily bridged with a Story Map to help present complex problems and open other opportunities among their communities. As seen in this research project, working towards a solution to the lionfish invasion can bridge the gap between the two groups and may will prove a critical role in community involvement in the future.

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