# An Analysis of Shark Attacks in the State of Florida

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## Abstract

In the state of Florida, there are approximately five shark attacks that occur annually. To date, shark attack "hot spots" throughout the state appear to be purely anecdotal, rooted in local lore. The goal of this study was to identify areas of high shark attack occurrence. Data of over 500 documented attacks in Florida, spanning three centuries, were used in this study. Volusia, Brevard, and Palm Beach counties accounted for 63% of all attacks. Each county has a more-localized area where attacks occur. Each site has specific attributes that are believed to be partly responsible for the high number of attacks, such as the presence of a lagoon or being a popular surfing location. However the aforementioned counties only accounted for 9% of all fatal attacks. Therefore, results suggest that while there are observable trends regarding the number of attacks that occur in a local area, fatal attacks follow no such pattern. The economy of Florida, especially local coastal towns, relies heavily on tourism. A single shark attack can have a detrimental effect on an economy. Understanding where attacks occur frequently, and why, may be beneficial in minimizing the negative economic effects of an attack.

**Keywords**: Shark Attack, Florida, Population Growth

Shark attacks are a rather rare occurrence. Coastal drownings far exceed fatal shark attacks. Furthermore, injuries sustained from other marine fauna, such as jellyfish and stingrays, easily outnumber shark attack injuries (Burgess and Simpfendorfer, 2005). Despite the low frequencies of annual shark attacks, around 68 (ISAF, 2014), perception of the risk of an attack is usually high (Leiserowitz, 2004). The media has sensationalized shark attacks. After Spielberg's 1975 summer thriller Jaws was released, the general public was horrified to leave the safety of the sandy beach (Camhi, 2008; Fordham and Cavanaugh, 2005). Few people can truthfully say that they do not think about a possible encounter with a shark upon entering the ocean.

Evolution has tuned sharks to near-perfection over the roughly 400 million years of their existence (O'Bryhim, 2006; Camhi, 2008; Compagno, 2008). At least one species is found in every ocean. Nearly all species inhabit coastal waters out to continental shelves; there are less than 40 described species that are considered pelagic (Compagno, 2008). Sharks are apex predators in all ecosystems in which they are present (Helfman, 2009). However, not all sharks are responsible for attacks on humans. Out of the over 440 described species of sharks, only 41 species are associated with a documented attack, with 12 of those having only a single incident (O'Bryhim, 2006). Three species, bull (Carcharhinus leucas), great white (Carcharodon carcharias), and tiger sharks (Galeocerdo cuvier) are responsible for over half of all documented attacks (Burgess and Simpfendorfer, 2005).

Since 1920, there are twenty states with documented coastal shark attacks (ISAF, 2014). This paper examines shark attack data collected off the coast of Florida. Florida was chosen for this study based on two main factors: the frequency of shark attacks and the socioeconomic impact of shark attacks on Florida's coastal communities. Florida has more recorded shark attacks than all

other states combined, and over five times as many as the state with the second most attacks, Hawaii (ISAF, 2014). If all recorded attacks were evenly spaced out along the coast, Florida averages an attack roughly every two miles. Additionally, the frequency of attacks happening in Florida is considerably higher than any other state. Since the late 1800s Florida has averaged 5.2 attacks annually while all other states average below one per year (Hawaii is the second highest with 0.73 per year; ISAF, 2014). A final factor is the amount of fatal shark attacks. Florida has had eleven, more than any other state (ISAF, 2014). All of these factors have led to Florida being infamously nicknamed the shark attack capital of the world.

Although a shark attack may only last mere seconds, the results can be devastating on both the victim and the economy of a coastal community. Injuries, if any, sustained from an attack can range from slight cuts and bruises to death where only portions of the remains are recoverable (Tricas, 1997). An economy that relies heavily on coastal tourism can be negatively impacted by a shark attack. A shark attack resonates with visitors and may deter them from visiting the beach. This lack of coastal tourism creates an economic deficit in the affected beach community, and can have severe consequences on the local economy (Achen and Bartels, 2004).

Florida's economy relies heavily on tourism. An estimated $71.8 billion is generated by tourists. The state saw a record 91.5 million visitors in 2012 (Florida DEO, 2012). Florida's beaches are a major tourist attraction with approximately 92% of beach-going tourists travelling from other states, therefore bringing money into the state (Murley et.al., 2005).

With an increase of visitors in Florida's beaches comes an increase of human-shark interactions. However, other factors are in play when examining causes of the general rise of the number of shark attacks throughout the past decades, such as global climate change: increasing sea temperatures are shifting fish populations, forcing predators to follow (Perry et al., 2005). These shifting populations affect the species distribution of both sharks and fish. A multi-decadal study in the North Sea examined spatial movements of local fishes. Researchers concluded that approximately two-thirds of present species showed movement, including several commercially-important fishes such as: (from top) cod, anglerfish, and snake blenny (Fig.1). Spatial shifts of shark populations tend to be near shore, as they follow prey. Shifting distributions of sharks coupled with an increase in human use of coastal areas may be the root causes that have led to the steady climb in shark attacks. George Burgess of the Florida Museum of Natural History explains shark attacks as a lottery system. If there is a single person in the water, the chances a shark comes into contact with them is low. However, if that shark is swimming in the same body of water with a hundred people present in the water, the chances increase. So with more people in the ocean comes a higher probability of a shark attack (Burgess, 2005).

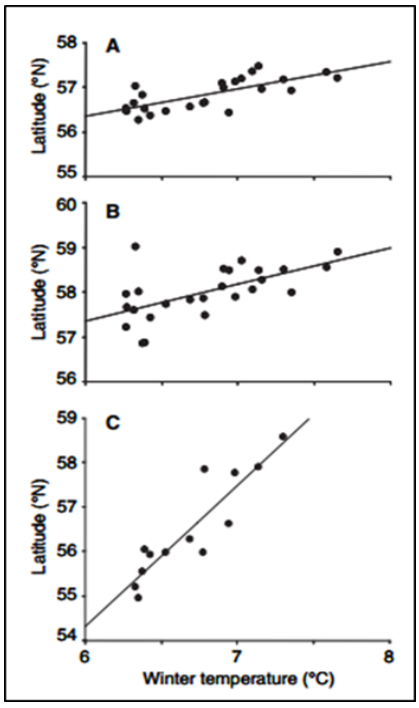


**Figure 1**. Relationship between mean latitudinal change of (a) cod, (b) anglerfish, (c) snake blenny, and average bottom temperature in their local habitat in the North Sea (Perry et al., 2005).

This study explores the spatial distribution of shark attacks in the coastal waters of Florida. Each attack is analyzed based on geographic location, water depth, time of day of attack and injury to the victim. The results of this analysis will highlight historical trends and illustrate geographic hot spots of shark attacks of Florida.

Shark attack data used in this study originated from the International Shark Attack File (ISAF) which is overseen by the American Elasmobranch Society along with the Florida Museum of Natural History. The ISAF is a collection of all known shark attacks throughout the world. It currently covers more than five-thousand individual attacks, ranging from the mid-1500s to present day. A majority of the cases that make up the ISAF are voluntary submissions. In addition, regional observers forward data (press articles, photographs, interviews, etc.) to the ISAF for further examination and possible inclusion into the database.

Data supplied for this study included all confirmed, documented shark attacks that have occurred in Florida (n=688). The earliest case occurred in 1882 and the most recent used in the study happened in mid-December 2013. Details of each shark attack included: victim outcome (fatal or not), general location (usually name of beach), Cartesian coordinates, date and time of attack.

Spatial data analysis was performed using ArcGIS. The complied shark attack data was imported into ArcGIS and point events were created based on the Cartesian coordinates of each attack. Twenty attacks were lacking these coordinates. Fortunately, these occurred within the last decade. Therefore, newspaper articles regarding each attack were examined for general geographic information for where the attack occurred. Many of these articles noted the depth of the victim (e.g. waist deep) or what the victim was doing at the time of the attack (e.g. surfing). A general bathymetry dataset was used for reference and through GIS, these attacks were geocoded in approximate locations where depth was provided in the articles. For surfers, which pertained to a majority of the attacks lacking location details, Google Earth was used to locate where surfers were at each specific beach site; from there, the attack spot was geocoded at that general location. For example, a newspaper article regarding an attack noted that the surfer was paddling into a wave when the attack occurred. Therefore, the point was recorded where the waves begin to break.

Zones were overlaid on the coastal waters, with a maximum distance of one mile out to sea. Although several shark attacks occurred at a distance that exceeded this one mile cutoff, these attacks were mainly in the open sea, and have little effect on coastal communities. A total of five zones were constructed in ArcMap. Further analysis in ArcGIS showed the number of attacks that occurred in each zone.

To create shark attack hot spots within the state, a point density analysis was performed on the data. This spatial analysis calculates the proximity of points. If a single point has a large number of other points near it, the assigned value will be high. Conversely, a point that is not in close proximity of other points will be assigned a lower value.

Several other datasets were used with the shark attack data. To examine which shark species are common in certain areas, geographic locations were provided for the species that have been identified in relation to an attack (Table 1). All other datasets were downloaded from the Florida Geographic Data Library. Bathymetric contours of Florida were used to determine the relative

depth of the victim at the time of attack. Additionally, a GIS base map provided by ESRI was used. Its primary purpose was for reference of geographic features that may explain the density of shark attacks taking place in this location (i.e. an inlet). NOAA satellite imagery was also considered in the analysis.

Microsoft Excel was used for all other data analysis. Approximately 77% (n=527) of all attacks within Florida had a time of day at which the attack occurred. All others had a general record (i.e. early morning, late afternoon). Only attacks that possessed a time of day were used when to quantify at what time most attacks have occurred. Early (1:00-6:59) and late (20:00-24:00) hours were grouped together due to low attack numbers.

| Common Name | Scientific Name | % of Attacks Responsible For |
|---|---|---|
| Bull Shark | *Carcharhinus leucas* | 20 |
| Blacktip Shark | *Carcharhinus limbatus* | 20 |
| Spinner Shark | *Carcharhinus brevipinna* | 16 |
| Scalloped Hammerhead Shark | *Sphyrna lewini* | 13 |
| Nurse Shark | *Ginglymostoma cirratum* | 7 |
| Sand Tiger Shark | *Carcharias taurus* | 6 |
| Lemon Shark | *Negaprion brevirostris* | 5 |
| Tiger Shark | *Galeocerdo cuvier* | 5 |
| Sandbar Shark | *Carcharhinus plumbeus* | 5 |
| Blue Shark | *Prionace glauca* | 2 |
| Shortfin Mako Shark | *Isurus oxyrinchus* | 1 |

**Table 1**. List of all shark species with a recorded attack in Florida which inhabit coastal waters of Florida.

## Results

The point density analysis performed in ArcMap displays geographic hot spots for shark attack activity (Fig. 2). The county with the most shark attacks was Volusia (n=257) followed by Brevard (n=114). It is no coincidence that both of these counties have some of the most coastline of the state of any of the other counties. The map also illustrates the third highest count being Palm Beach (n=64), which also possess a long coastline. Aside from these three counties with the highest number of shark attacks, a sharp decrease in the number of attacks is observed. Regarding fatalities resulting from the shark attack, both Duval and Pinellas counties are the highest in this category [Fig. 3 (n=2)]. Seven other counties have had one fatal shark attack in their waters; neither Volusia nor Palm Beach has had a documented fatality and Brevard has had only a single one.

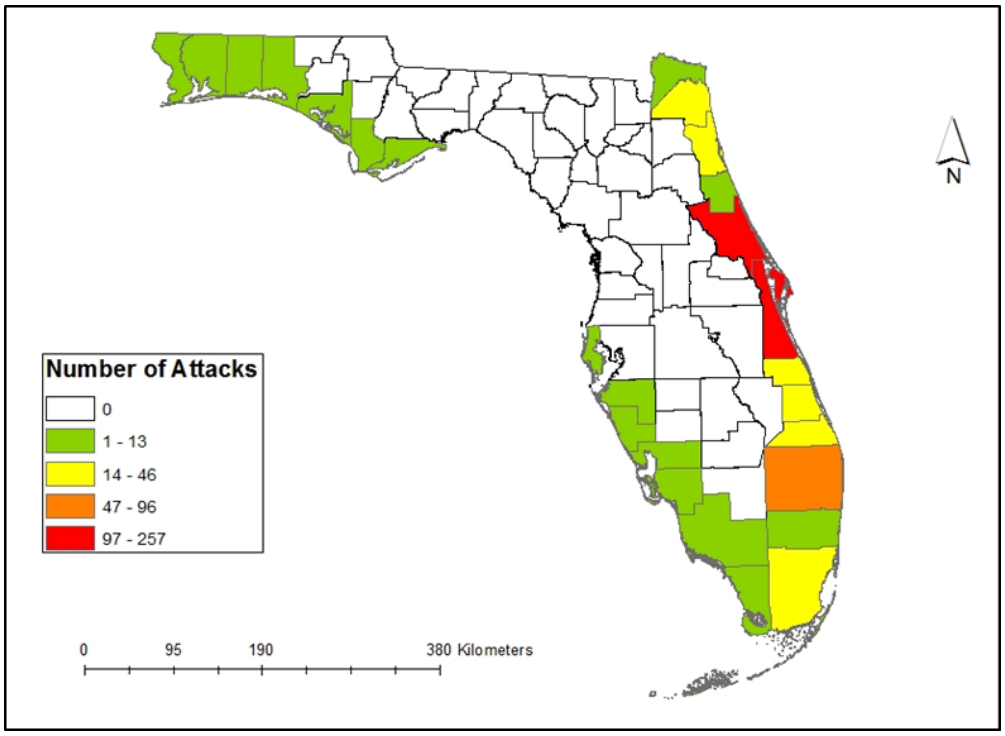


**Figure 2**. Map of Florida representing the number of shark attacks that have occurred since 1882. (n=688)

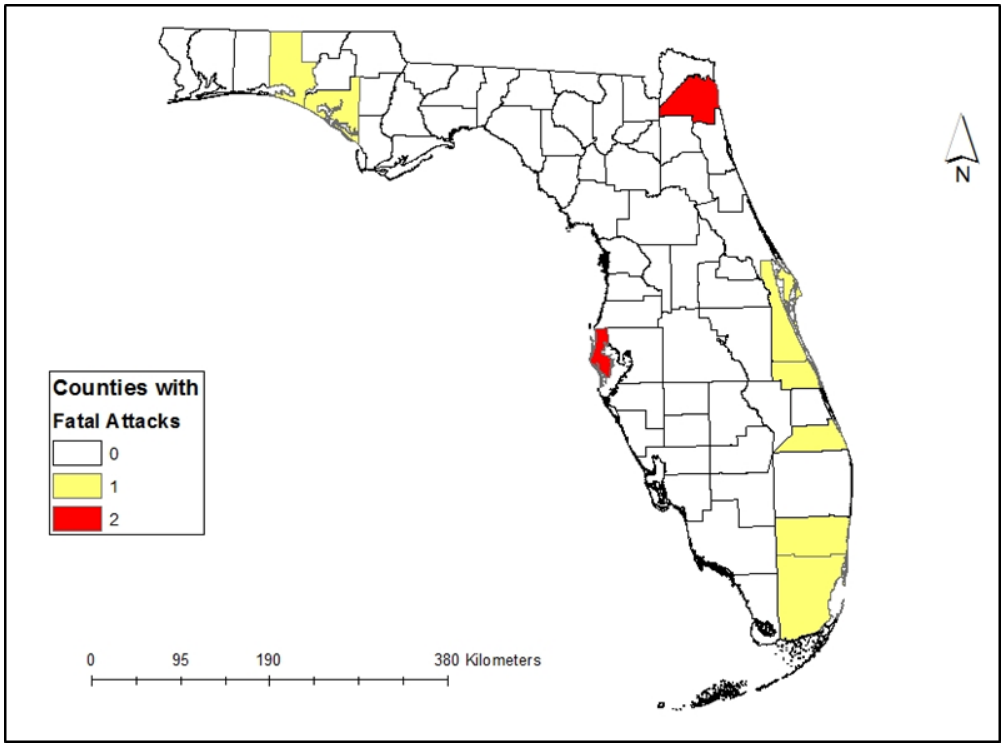


**Figure 3**. Map of Florida showing the number of fatal shark attacks. (n=11)

Using a discrete, bathymetric data set, shark attack depth ranges were observed. Nearly all attacks occurred in water below 1.8 meters, with the second highest depth ranging from 1.8- 3.7 meters. This was expected, since most beachgoers who enter the water do not go out to where they can no longer touch the bottom. At some areas, although dominated by the shallower depth range, there was an increase in attacks in waters deeper than 3.7 meters. These areas were found to be popular surfing sites Therefore, the deeper attacks may have been occurring due to a high number of surfers present in the water. Similar results were discovered when looking at the attacks in the different zones. Of the five zones set up along the entire coast, the zone that had the highest number of attacks was the one closest to shore. Each zone that was farther out from shore recorded less attacks.

As expected, attacks occurred in the time of day when bather loads are at their highest (Fig. 4). After 6:00, attacks slowly increase until a spike is observed at 11:00, where attacks remain high until15:00. However, attacks appear to increase again at 16:00, followed by a general decrease for the remainder of the day.

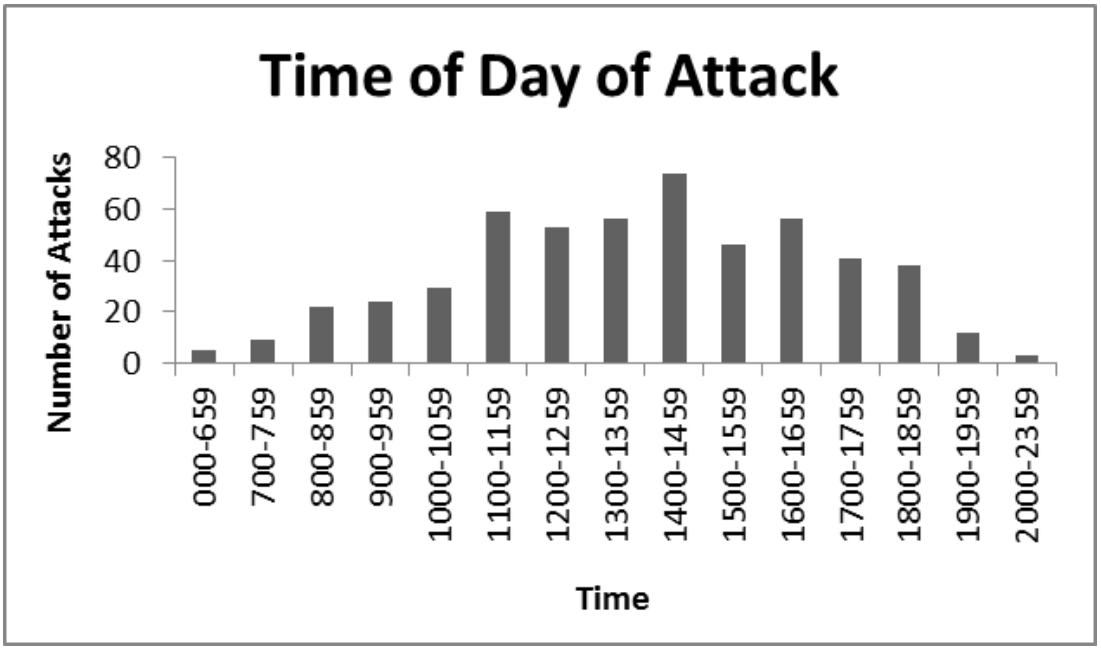


**Figure 4**. Number of shark attacks occurring throughout the day. (n=527)

**Discussion**

The most striking evidence the data presented was how many more shark attacks occurred in the aforementioned three counties, before dropping off. Volusia county had the most attacks (n=257). One key feature that may explain the high abundance of attacks in these areas is the geographic makeup of the local coasts. Approximately 35% of these attacks (n=91) have occurred within 800 meters, north or south, of the inlet at New Smyrna Beach (Fig. 5).


**Figure 5**. Map of the inlet near New Smyrna Beach, Florida. Yellow points represent shark attacks.

A similar occurrence is observed at the Palm Beach Inlet located in Palm Beach County, where roughly 41% (26 out of the total 64 attacks) are located within two kilometers of the inlet's mouth. Inlets are areas that can be characterized by their nutrient-rich water being discharged into the ocean. Some inlets act as the mouth of an inland river while others are the entrance to a lagoon. The inlet at New Smyrna Beach is where the ocean meets the Halifax River, a 40 km. long river that is part of the Atlantic Intracoastal Waterway. Historically, the Halifax River has been known for excellent recreational fishing. Popular species that inhabit these muddy waters include:

sheepshead (*Archosargus probatocephalus*), tarpon (*Megalops atlanticus*), and snook (*Centropomus undecimalis*). More recently, schools of mullet (*Mugil cephalushave*) have been common in these waters, especially at the inlet's mouth (Kelly, 2013). Fishing at both inlets is prominent. Many of these fishes that are sought after by fishermen are also popular prey for sharks. Mullet are popular prey for many species of sharks and coastal waters should be considered dangerous when they are present at a high abundance (Bester, 2004). Blood, among other fluids, will be given off by a fish that has been hooked by a fisherman. The highly sensitive olfactory senses of sharks can detect extremely small traces of blood and other fish fluids (Compagno et al., 2005). Even a lack of current will not prevent the shark from finding the source. Blacktip and Gray Reef sharks can detect these fish extracts at a rate of 1 part per 10

billion, similar to a single drop in an Olympic-sized swimming pool (Helfman, 2009). These cues are picked up by nearby sharks, whom become excited and go into a feeding mode (Baldridge, 1974). A study performed by Baldridge (1966) found that only when dead rats were wetted with fish fluids, sharks would attack; rat blood appeared to have no effect. Heavy fishing taking place throughout the inlet may be eliciting the present shark population into a "feeding mode."

The two jetties present on both sides of the inlet are a popular location for surfers (Scarfe et al., 2003). Nearly all the attacks observed in this location occurred in overhead water, roughly 5.5 meters in depth. Furthermore, the locations of the attacks are just seaward of the breaking waves, suggesting the victim may have been a surfer waiting beyond the breaking waves. A study by Baldridge (1974) which examined different aspects of shark attacks noted approximately 10% involved surfers. It has been shown that while moving over the water, the fins of surfboard give off vibrations that can be picked up by fishes (Baldridge, 1974). Coupled with the splashing of the surfer, the sounds being given off may attract a curious shark.

The inlet in Palm Beach County is the entrance of the Lake Worth Lagoon. This lagoon is landlocked, except for the inlet. The geographic nature of this lagoon allows it to serve as an excellent nursery for many marine species, including sharks and their prey (Snelson, 1984). With a large number of ichthyofauna moving in and out of the lagoon, predation will be high.

Both the New Smyrna and Palm Beach inlets are sites where marine predation is high. Additionally, a high bather load is also common at both sites (Kelly, 2013). With this comes the possibility of misidentification of a human for a fish, which can be an unfortunate and deadly occurrence.

When examining the areas where fatal shark attacks occurred, no geographic indicator is observable. Prior to looking at the data, it was expected that the counties with a high number of attacks would also record a high number of fatalities. However, this expectation is dismissed since Volusia County, which recorded the most attacks, has not had a single fatal one. Furthermore, Walton County has only experienced one shark attack, which was fatal. All species found in Florida’s coastal waters that are known for attacking in a fatal manner are found in all counties with fatalities. When examining all of the variables that account for an attack, the local geography plays an extremely small role in determining if there will be a fatal outcome. Certain variables such as age and health of the person and location of the bite, among others, come into play much more.

From the attacks where a specific time was given, there appears to be no increase in attacks at dawn or dusk. Research on three different shark species, two of which are responsible for attacks in Florida (lemon and hammerhead) show no diel feeding patterns (Cortés, 1990; Cortés, 1996; Preti, 2001). Naturally the number of attacks increases during midday and the early afternoon, when beaches are at their busiest.

The species ranges did not yield any profound results. Of the species local to Florida, most all of them overlap each other. Therefore, it would be impossible to assign an individual attack to a certain species with little uncertainty. However, some recorded attacks can be charged to an individual species with little error. The bull shark (Carcharhinus leucas) is one of few species,

and the only one native to Floridian waters, that can survive in a rather freshwater environment (Snelson, 1984). In fact, this species is known to go hundreds of miles inland, through freshwater rivers. In the 1930s, a juvenile bull shark was caught in Illinois, nearly 2900 km. upriver from the Gulf of Mexico (Moss, 1984). Attacks have taken place in coastal, brackish waters; for example, the attack that occurred approximately 20 km. upstream in the St. John's River in Duval County (Fig. 6). Few species, other than the bull shark could enter waters that far inland. Being that the only species on this short list that inhabits Florida's waters is the bull shark, while the others are endemic to the southwest Indo Pacific, this upriver attack can be assigned to that species (Compagno et al., 2005).


**Figure 6**. Map of the mouth of the St. John's River in Jacksonville, Florida. Yellow points represent shark attacks.

Florida, along with California and Texas, are projected to be responsible for 46% of the total population increase the United States will be experiencing in the next coming decades (Metzger, 2012). By 2030, Florida is expected to grow by approximately 17%, to a total population of 23.6 million. With more people in the state it should be assumed that more people will be either living at or visiting the coast. The Florida Department of Transportation examined Florida's estimated population growth at the county level, projecting where in the state the population increases will occur (Fig. 7).

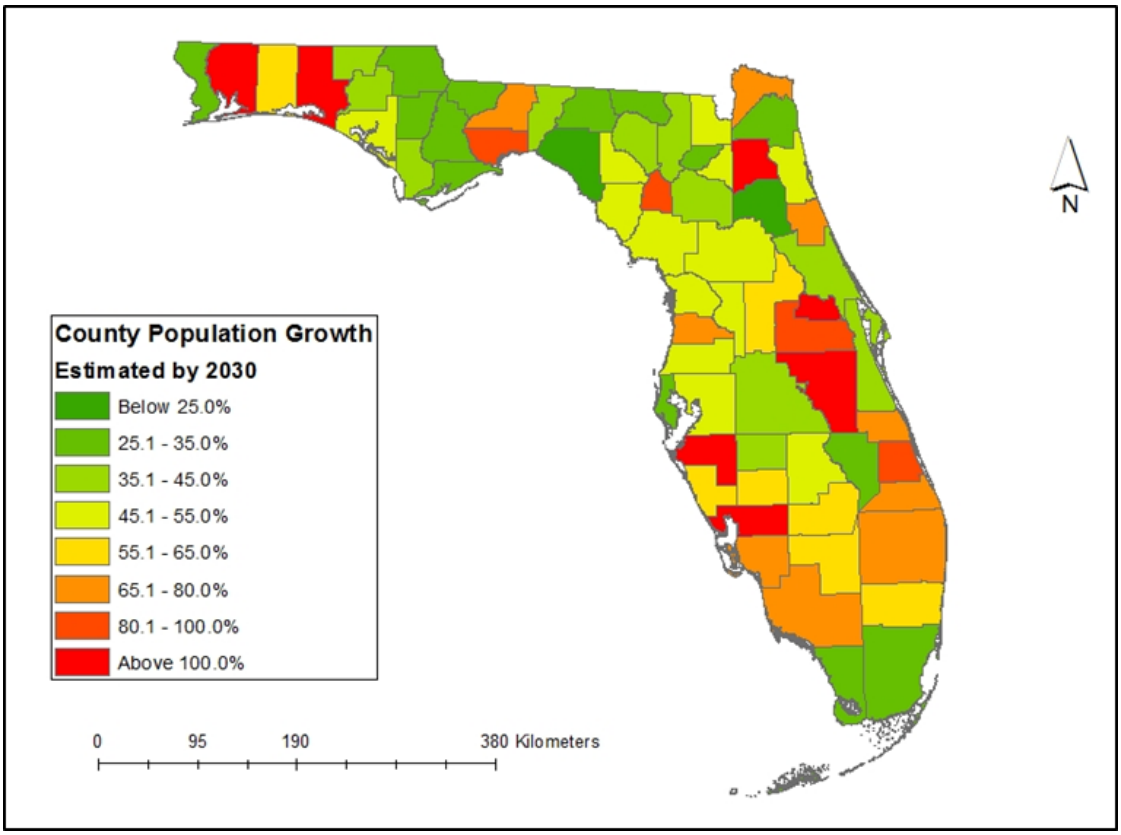


**Figure 7**. Map illustrating the estimated, expected growth in population for each county in Florida by year 2030.

Seven counties are expected to double in population by year 2030: Charlotte, Clay, Manatee, Osceola, Santa Rosa, Seminole, and Walton (Florida DOT). All of the counties are coastal, with the exception of Clay, Osceola and Seminole. Additionally, these four coastal counties all have documented shark attacks, from just one (Charlotte and Walton) to four (Manatee). Furthermore, Clay, Osceola, and Seminole can all still have an effect on the number of shark attacks despite not lying on the coast. All three counties lay just a single county away from the coast. So an increase in the permanent population of Osceola and Seminole will most likely increase the beach visitations of Brevard and Volusia, while Clay may have an effect on St. John's County. With a large number of permanent residents, it can be expected that there will be more beachgoers.

## Conclusion

The state of Florida has historically recorded more shark attacks than any other state in the United States. Still today, yearly shark attacks occurring in Florida continue to be comparatively high to other states. When examining the complete list of recorded attacks in Florida, trends are observable. Three counties act as hot spots for attacks: Volusia, Brevard, and to a lesser extent, West Palm. Within these counties, inlets appear to be the geographic areas where attacks are concentrated. This is most likely due to the fact that both humans and shark are attracted to inlets, for recreation and predation, respectively.

Although attacks seem to be concentrated in certain areas throughout the state, fatal ones follow no such trend. The few fatal shark attacks that have happened are scattered about the state's coastline. All of the fatalities occurred at different times and places within the coastal waters. Additionally, all species' ranges occur where the fatal attacks occurred. It appears that a person who is unfortunate enough to be fatally attacked may have just had even more back luck than a person who is non-fatally attacked.

To date, there is no effective way to completely prevent shark attacks. The inherent risk upon entering the ocean of coming into contact with a shark will most certainly always remain present. If complete avoidance from shark attacks is not possible, knowledge about how to lower one's chances should be of high importance. Educating beachgoers on ways to reduce the risk of an attack can go a long way to help lower yearly attacks. Although Florida is a regional hot spot for shark attacks, other locations around the world could benefit from similar studies of analysis on local attacks.

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