PUBLIC PERCEPTION OF COASTAL HAZARDS AT WAIKĪKĪ BEACH, HAWAI‘I, WITH A FOCUS ON THE BOX JELLYFISH *ALATINA ALATA*

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Table of Contents

List of Tables

List of Figures

Chapter 1: General Introduction

Coastal areas present a wide variety of risks and hazards to humans. With nearly half the world's population living within 150 km of a coastline (United Nations Atlas of the Oceans), such risks and hazards mean that a large percent of the population potentially encounters these risks and hazards. Amongst the potential hazards are encounters with marine organisms and nonbiological physical factors that can result in human injury or death (Bagnis et al. 1979; Wetherbee et al. 1994; Kirkpatrick et al 2004; Gershwin et al. 2010; Gibbs & Warren 2015). Harsh physical conditions such as strong currents or high surf can result in drowning, which is the 3rd leading cause of unintentional deaths worldwide (WHO Drowning Fact Sheet, 2018). Sharks and jellyfish are generally encountered close to shore and pose hazards due to direct physical danger to humans, whereas bacteria, algae, and other microorganisms present hazards via ingestion from seawater or through consumption of seafood items that have accumulated toxic by-products through the food chain, such as filter feeding bivalves (Kirkpatrick et al 2004) or reef fish that accumulate ciguatoxin (Bagnis et al. 1979). The interactions that occur between humans and coastal hazards are essential areas of study for preventing as much harm as possible.

Human-wildlife Conflicts

Human-wildlife conflict can occur when an organism harms a human directly, interferes with human activities, or impacts resources (e.g. to property, livestock). On land, carnivores and venomous organisms are often feared due to their capacity to injure or kill human beings, livestock, or pets (Treves & Karanth 2003; Boissonneault et al. 2005; Gershwin et al. 2010). White-tail deer (*Odocoileus virginianus*) are common throughout the continental US and may present problems due to car accidents or damage to property (Bissonette et al. 2008). People affected by White-tail deer are more likely to support a management plan to reduce injurious interactions (West & Parkhurst 2002). In the ocean, human interactions with marine wildlife can be more frightening than land encounters as human movement is more restricted underwater. Human interactions with sharks are sometimes violent or fatal and have been covered in the media for decades, which has created widespread fear of sharks (Boissonneault et al. 2005; Friedrich et al. 2014; Gibbs & Warren 2015; McCagh et al. 2015). As human populations grow, conflicts between humans and wildlife can potentially increase as more people are exposed to hazards (Wolch et al. 1997; Cutter & Finch 2008). With more people becoming exposed to hazards in many regions (Cutter & Finch 2008), there is a need for management plans that address human-wildlife interactions. On Oʻahu, Hawaiʻi, coastal human-marine wildlife interactions are generally between humans and shark- or jellyfish species, which differ across beaches and islands. Tiger sharks and reef sharks can be found around the island of Oʻahu in coastal waters year-round with peaks in abundance correlated to the summer and fall seasons (Parrish & Goto 1997; Whitney et al. 2011). Records of shark encounters indicate that the severity of encounters range from non-violent to fatal (http://dlnr.hawaii.gov/sharks/shark-incidents/incidents-list/). Several jellyfish species are found on Oʻahu which include *Cassiopea* spp. (Holland et al. 2004), several jellyfish species in Carybdeidae (Crow et al. 2015), and *Physalia utriculus* (Yanagihara et al. 2002). Jellyfish venom has been studied extensively, in large part to discover an effective treatment for stings (Nagai et al. 2000; Wiltshire et al. 2000; Chung et al. 2001; Thomas et al. 2001; Nomura et al. 2002; Tibballs et al. 2011; Ward et al. 2012). To date, no treatment that is guaranteed to alleviate pain has been found.

Impacts to Humans from Jellyfish

Jellyfishes are gelatinous organisms, belonging to the phyla Ctenaphora, Cnidaria, or Tunicata, that can be observed in many parts of Hawaiʻi. Cnidarian jellyfish possess venomous nematocysts that can injure or kill humans that are stung (Gershwin et al. 2010; Tibballs et al. 2011), which is a cause for concern to coastal communities and ocean amenity user groups. Additionally, jellyfish in high densities can clog fishing nets, damage power plant cooling systems, interrupt desalination plant operations (Daryanabard & Dawson 2008; Nagata et al. 2009), and populations of commercial resource fish can be impacted by the presence of some jellyfish species (Lyman et al. 2005; Robinson et al. 2014). On Oʻahu, two common species of Cnidarian jellyfish deliver painful stings to beach users: the box jellyfish or sea wasp (*Alatina alata*) and the blue bottle jellyfish (*Physalia utriculus*). In Waikīkī, box jellyfish influx to beaches each month following the moon cycle. Influxes were observed for 14 years in Waikīkī every month, with anywhere from 5 to 2000+ individual box jellyfish observed (Chiaverano et al. 2013). Coupled with increasing populations of people, stings from these jellyfish may become more common.

A perceived increase in jellyfish abundance was observed for several decades within coastal regions such as the Black Sea, the North Sea, the Northeastern coast of the US, and Eastern Asia (Greve & Parson 1977; Mills 2001; Lynam et al. 2005; Richardson et al. 2009;

Purcell 2012; Gibbons & Richardson 2013). The ctenophore *Mnemiopsis leidyi* in the Black Sea and surrounding areas is a prominent example of a harmful jellyfish, which heavily impacted local fisheries during the 1980s and 1990s when abundance increased rapidly (Shiganova et al. 2001; Kidey 2002). Overfishing has been linked to increased abundance of jellyfish, possibly due to decreased competition for prey resources between gelatinous plankton and harvested species (Purcell et al. 2007; Robinson et al. 2014). Global climate change has also been examined as a possible factor in increasing jellyfish abundance and influx nearshore (Purcell 2005; Jacups 2010). Although jellyfish abundance appears to be increasing, recent research suggests that jellyfish abundance oscillates on large time scales and the perceived increase in abundance may be due to observations that primarily began during the rising phase of some jellyfish cycles (Chiaverano et al. 2013; Condon et al. 2013; Gibbons & Richardson 2013). These studies suggest that increased efforts to mitigate global climate change, overfishing, and coastal eutrophication may not address the challenges associated with human-jellyfish interaction, and management plans specifically targeted at jellyfish may be necessary.

In Australia, jellyfish are a major risk to human life due to the box jellyfish or sea wasp (*Chironex fleckeri*), which aggregates to the Northern coasts of Australia on a seasonal cycle (Gordon & Seymour 2012). *C. fleckeri* is considered the most venomous organism on earth and their sting can kill a human being within minutes (Gershwin et al. 2010). Massive offshore net enclosures are used to mitigate the impact of *C. fleckeri* on beach users in Australia (Uninet Enclosure Systems), although smaller stinging jellyfish may be able to enter the enclosure. *Carukia barnesi* is a common species of stinging jellyfish that may enter the enclosures and cause injury to beach users (Harrison et al. 2004). Many of the residents and visitors in Australia have at least a basic awareness of jellyfish issues so that injury or death can be avoided (Harrison et al. 2004).

A jellyfish sting has the potential to dampen beach user experiences that would otherwise be positive, creating an ecosystem disservice. Ecosystem disservices are defined as ecosystem functions that negatively affect human beings in some way (Lyytimäki & Sipilä 2009; Dunn 2010; Gomez-Beggethun & Barton 2013). A jellyfish sting causes pain for a short period of time, up to several hours, and may result in additional costs associated with pain relief or medical treatment in the case of an allergic reaction (Gershwin et al. 2010). The best method of pain relief for *A. alata* (as *Carybdea alata*) is a matter of debate in the medical community, however hot water is currently considered the best method with the caveat that access to hot water on the beach is often limited (Nomura et al. 2002; Ward et al. 2012). Prevention therefore appears to be the best method for mitigating costs to individuals in terms of either money or time.

Providing Jellyfish Information to Relevant Demographics

Increased knowledge of a species is correlated with an increased interest in conservation and respect for a species, such as sharks or dolphins (Thompson & Mintzes 2002; Barney et al. 2005; Friedrich et al. 2014). Beach users in the German Baltic Sea responded positively to information about jellyfish and were less concerned about jellyfish after receiving pertinent information (Baumann & Schernewski 2012). In Israel, 56% of survey participants stated that they would donate money to a hypothetical global initiative program to address the issue of jellyfish aggregating along coastlines (Ghermandi et al. 2015).

The box jellyfish *Alatina alata* is a regular nuisance to beach users on Oʻahu. Medusae of this species consistently aggregate on the south shore of the island, particularly at Waikīkī Beaches, each month 8-12 days after the full moon. This pattern has been statistically analyzed from monthly influx data with a correlation between jellyfish abundance and certain oceanographic parameters collected over a 14-year period (Chiaverano et al. 2013). During *A. alata* influxes, the box jellyfish are very difficult to see in the water and beach users may be stung in large numbers. A local news outlet has reported 50+ stings occurring in a day on multiple occasions over the past few years (February 2016: http://www.hawaiinewsnow.com/story/31124495/lifeguards-warn-thousands-as-oahu-shores-see-influx-of-box-jellyfish, July 2017: http://www.hawaiinewsnow.com/story/35926623/ouch-over-60-stung-by-box-jellyfish-in-waikiki). One of the largest recorded sting events occurred on July 30, 1997 when over 700 people were stung by *A. alata* on the south shore of Oʻahu. Hanauma Bay State Park also stopped operations for several days following a high influx of box jellyfish that resulted in over 200 beach users being stung (http://www.hawaiinewsnow.com/story/31124495/lifeguards-warn-thousands-as-oahu-shores-see-influx-of-box-jellyfish). *Alatina alata* belongs to the class Cubozoa, a group of derived jellyfish known for their sophisticated vision (Coates 2003), relatively strong swimming ability, active capture of prey (Hamner et al. 1995), and potent venom (Brinkman & Burnell 2009). Rather than build fear of *A. alata*, their unique biology and interesting ecology could be used to increase the public's interest and result in individuals becoming more willing to learn 1) about jellyfish when visiting Hawai‘i and 2) how to avoid stings by observing Lifeguard Service warning signs and not swimming during the typical influx period.

Interactions with box jellyfish can result in a sting if skin contacts the tentacles of the box jellyfish. A box jellyfish sting causes pain for a short period of time, up to several hours, and may result in additional costs associated with pain relief or medical treatment in the case of an allergic reaction (Gershwin et al. 2010). Hence, box jellyfish stings have the potential to dampen beach users’ experiences and thus can be considered an ecosystem disservice (Lyytimäki & Sipilä 2009; Dunn 2010; Gomez-Beggethun & Barton 2013). Because no method of pain relief for *A. alata* (as *Carybdea alata*) is known to cause complete pain relief (Nomura et al. 2002; Ward et al. 2012), prevention of interactions may be the best method for mitigating costs to individuals. One way to prevent human-jellyfish interactions is to stay away from the water when jellyfish are present. However, there are occasional sting events despite the availability of box jellyfish influx information online.

Enhancing public education regarding box jellyfish in Hawai‘i may alleviate unnecessary public concern, reduce the number of stings during large influx, or improve public outlook on jellyfish, which were investigated elsewhere (Baumann & Schernewski 2012; Donno et al. 2014; Ghermandi et al. 2015). Differences in background, experience, and social networks may also result in visitors and residents having different perceptions of jellyfish and other hazards. The Social Network Contagion Theory of Risk Perception concluded that people are more likely to share perceptions with members of their social networks than with outsiders (Scherer & Cho 2003; Muter et al. 2013). In Hawai‘i, visitors do not belong to the same social networks as residents, and may not have access to local knowledge of coastal hazards.

Hawai‘i supports a major tourism industry that attracts millions of visitors each year (Hawai‘i Tourism Authority Annual Researh Report 1999-2016). More than 5 million people visited O‘ahu in 2016, out of ~8.8 million total visitors to the state of Hawai‘i that year (Hawai‘i Tourism Authority Annual Visitor Research Report 2016). Hawai‘i is well known for its beaches and the most popular beaches on O‘ahu are in Waikīkī, which is a 3.2 kilometer stretch of beach on the southern shore of the island that is lined with hotels, restaurants, and retail outlets. With a resident population of nearly 1 million people in 2016 (State of Hawai‘i Data Book 2016) and a land area of ~1546 km^2, exposure to coastal hazards is likely to be high. A national examination of social vulnerability to natural hazards observed increases in vulnerability for O‘ahu for the period from 1960 to 2000 and further increases were expected into the 2010s (Cutter & Finch 2008). While most visitors may not want to consider potential hazards while in Hawai‘i, the high density of people may require greater awareness of potential dangers.

My research was conducted through the lens of box jellyfish aggregations at Waikīkī Beach as a model for beach user risk perceptions of coastal hazards. The sting from *A. alata* is non-lethal, and this cubozoan arrives at Waikīkī Beach on a predictable schedule, which allows reliable monitoring and ensures that beach users can avoid interactions. Outreach is likely to reduce risk and not be controversial with the public. The predictability of arrival allows beach users to plan their activities around the predicted influx dates if the public is made aware of jellyfish influx timing information. Information about *A. alata* is not currently available to the public at Waikīkī except when signs are posted. Some information is available online, although it is sometimes misleading. For example, the picture of a different species may be used to describe the box jellyfish that occurs at Waikīkī. Although the timing occurs with regularity, the magnitude of each influx is unpredictable. Current data show two periods of increase in magnitude within a 14-year period and counts between 5 and 2365 individual box jellyfish (Chiaverano et al. 2013). A beach user survey was designed to help us understand the impacts of providing information to both visitors and residents regarding their risk perceptions of box jellyfish, which was compared to other potential hazards, and impacts to their perceptions of Waikīkī in general.

Chapter 2: Survey of Beach Users at Waikīkī

Jellyfish presence is currently expressed to beach users with jellyfish warning signs on the beach (Figure 1). Similar signage is used to warn against sharks when they are sighted. In a preliminary study on the box jellyfish (Holland et al. unpub.), 100 surveys showed that beach users frequently did not notice the jellyfish warning signs and were therefore unaware of jellyfish presence on days that these signs were posted. This preliminary result suggests that current signage may not be effective in helping beach users avoid box jellyfish stings. Additional public education may alleviate unnecessary public concern, reduce the number of stings, and improve public outlook on jellyfish (Baumann & Schernewski, 2012; Donno et al., 2014; Ghermandi et al., 2015). Interactions with jellyfish may then change from negative interactions resulting in stings to positive interactions resulting in knowledge gained about a marine organism.

The primary objective of this research is to determine public perception of risk towards *A. alata*, whether *A. alata* impacts beach users' enjoyment of Waikīkī Beach, and whether beach users' perceptions would change after receiving information about box jellyfish and how to avoid stings in Waikīkī. In order to better understand the human conflict with box jellyfish in Waikīkī, I seek to identify: 1) the perceptions and knowledge of beach users that informs risk associated with box jellyfish, 2) the differences in perception of risk that beach users may have for individual hazards (i.e. risk associated with poor water quality may be different than risk associated with jellyfish stings), and 3) the impact of providing information about marine wildlife hazards on beach user perceptions of risk towards the marine wildlife hazards and their perceptions of the beach where the hazards are encountered. To investigate these points, I have developed four hypotheses:

Visitors to Hawaiʻi perceive marine wildlife (box jellyfish and sharks) as a greater risk to their safety if they were previously aware of jellyfish.

Beach user characteristics could create differing reactions among various groups of people to the presence of box jellyfish. Awareness of box jellyfish presence at Waikīkī may lead beach users to be more concerned about potential encounters with jellyfish than someone who is not aware of box jellyfish influx. If beach users are aware of the potential risks that the jellyfish at Waikīkī pose, they may have an informed perception of risk towards the jellyfish found at Waikīkī and as the sting is painful, concern is expected to be higher for those aware of box jellyfish presence. Additionally

Beach users perceive the box jellyfish, A. alata*, to be of greater concern than other hazards and other species of marine wildlife at Waikīkī.*

The box jellyfish *A. alata* appears at Waikīkī for up to 5 days a month whereas other hazardous species make less frequent appearances. Sharks are rarely sighted at Waikīkī and their peaks in abundance tend to be in the summer or early winter months (Parrish & Goto 1997). Other species of jellyfish are not found at Waikīkī, although there are other species of jellyfish that can be found in other areas of Oʻahu (Crow et al. 2015). Related to environmental hazards, Waikīkī has mostly calm waters that can become rough during southern swells and poor water quality is uncommon: there have been infrequent incidents when sewage leaks have compromised the safety of the beach. Therefore, the box jellyfish should be of greatest concern as it is the most frequent hazard that can be encountered at Waikīkī.

After receiving information, concern regarding marine wildlife will significantly decrease.

Beach users received the following information as part of this study: the frequency with which jellyfish can be found at Waikīkī, the intensity of the sting from the jellyfish, the fact that no deaths have occurred from jellyfish stings at Waikīkī, the seasons when sharks are most likely to appear at Waikīkī, and recommendations to remain out of the water when warning signs are posted (Appendix II). This information may help to alleviate risks by providing beach users with more information to help them make decisions about whether to go to Waikīkī Beach and participate in water activities, especially on a short vacation. This information is also expected to prevent misconceptions of jellyfish at Waikīkī that may arise from the vagueness of the warning signs that are currently posted.

Information about marine wildlife hazards will have little to no impact on the enjoyment of Waikīkī for beach use and the differences in enjoyment will be due in part to beach users, prior awareness of jellyfish.

The marine wildlife hazard information presented to beach users in this research is designed to decrease concern regarding those hazards. Thus, this information is expected to reduce concern, which should not impact enjoyment of the beach. Awareness of marine wildlife hazards is likely to impact how an individual would process information about box jellyfish. For beach users that were previously aware of jellyfish, provided information is expected to decrease concern as beach users will be made aware of the relatively low risk in coming to serious injury due to jellyfish or sharks at Waikīkī. Alternatively, if beach users are not aware of marine wildlife hazards prior to receiving information, their concern is expected to increase as they are now aware of potential risks to their safety where there would have been no prior concern.

Methods

To address the research objectives, I investigated beach user risk perceptions regarding the box jellyfish *Alatina alata* using a public survey at Waikīkī, Oʻahu, Hawaiʻi. Box jellyfish routinely appear at Waikīkī 8-12 days after a full moon. University of Hawaiʻi researchers documented 14 consecutive years of *A. alata* (as *A. moseri*) influx at Waikīkī Beach between lifeguard's towers C & D (Chiaverano et al. 2013) where it is hypothesized that the jellyfish are spawning. Thus, this scheduled routine along with the high influx of visitors to Waikīkī beach creates a situation of reoccurring human-wildlife conflict; an ideal location for administering a survey on the knowledge and perception of beach users on jellyfish encounters.

I administered the survey between lifeguard station 2B and station 2F (Figure 2), which is approximately 400 meters in length. The study was conducted between October 2016 and July 2017. Surveys were fielded on a total of 37 days within the study period, 17 of which occurred during jellyfish presence. A total of 5-20 surveys were completed each day over a 1- to 6-hour period. Surveys were conducted on days when jellyfish warning signs were posted as well as when no signage was present. Days when jellyfish were present generally coincided with the 3rd or 4th week of the month during the study period. Participants within the survey area were actively approached without interrupting their engagement in other activities. Surveys were all conducted after 8 am, at which time lifeguards would have posted jellyfish signs if jellyfish were present at Waikīkī Beach.

Adult beach users at Waikīkī were interviewed in person regarding their personal awareness and risk perceptions towards the box jellyfish at Waikīkī Beach and briefly on other marine coastal hazards. The survey received IRB clearance for a Hawaiʻi permit (CHS#23404). All surveys were completely anonymous and were not delivered to any person under the age of 18. The survey was voluntary with no benefits or risks for participation and participants were not asked to provide any personal information.

A total of 400 surveys were collected during the survey period with a 28.8% refusal rate. The sample size for this study was determined for a 95% confidence interval with an approximated population of combined Hawaiʻi residents and visitors at 10 million people (8.8

million visitors and 1.2 million residents) and a margin of error of 5 (Sample Size Calculator, Creative Research Systems).

Public Survey Instrument

I developed a 23-question questionnaire that included close-ended and open-ended questions (Appendix I), which was evaluated and approved by the University of Hawaiʻi IRB(CHS#23404). The close-ended questions included ordinal scale questions, interval scale questions, and multiple-choice questions. The participants completed the first 15 questions, then they were presented with printed jellyfish and shark information, and then the participants could answer the remaining 8 questions. The separation was designed to measure the change in concern regarding sharks and jellyfish after information was provided to the participant as well as impacts that possessing this information might have on perception of the beach overall. The provided information was printed with images of *A. alata* on a sheet of paper (Appendix II). Participants received the information verbally and through viewing the information on the sheet. Participant responses used to answer hypotheses were from questionnaire questions #10, #11, #16, #17, #20, and #23 (Appendix I). Other questions used in analyses are detailed in the sections below.

Likert scales were used for 9 questions in the questionnaire. The scales were not the same for every question. Participants' level of concern associated with box jellyfish on Oʻahu were reported using a nine-point Likert scale from "0" meaning no concern to "9" meaning major concern. Participants also answered questions about their concern regarding general coastal hazards and species of marine organisms. Concern levels for abiotic hazards and shark hazards were collected in the questionnaire as a comparison to jellyfish concern. Concern levels for specific species were collected to understand whether participants could differentiate species and perceived different species and warranting different levels of concern. The selection of organisms in the specific species portion was based on general perceptions of aggressiveness or sting intensity and presence in Hawaiian coastal waters. Four species that occur on Oʻahu were selected to test the hypothesis that beach users perceive the box jellyfish to pose the greatest risk to safety at Waikīkī (sea wasp [*A. alata*], bluebottle [*Physalia utriculata*], tiger shark [*Galeocerdo cuvier*], and whitetip shark [*Triaenodon obesus*]). In this question, the more specific common name of "sea wasp" was used for Waikīkī's box jellyfish because the term "box jellyfish" is a catch-all term for any jellyfish in the order Cubozoa. Two other species (nurse shark [*Ginglymostoma cirratum*] and moon jellyfish [*Aurelia aurita*]) were also selected as comparisons in the above hypothesis though they are not generally found at Waikīkī and are generally low risk organisms. However, they are widespread globally and they can often be found in aquariums. These species were included in the questionnaire as a control to check participant knowledge about species distributions. If participants are aware of local species, then they should respond to both questions with “0” concern. Participants reported whether they had encountered either jellyfish or sharks previously and reported the impact of this experience using a five-point Likert scale that ranged from “1” meaning no impact to “5” meaning major impact. For jellyfish, the encounter was defined as receiving a sting whereas shark encounters were defined as general encounters. Participants reported the likelihood of jellyfish and shark information (Appendix II) having an impact on a potential revisit to Hawaiʻi using a Likert scale from “1” meaning very unlikely to “3” meaning neutral to “5” meaning very likely. Participants reported their general satisfaction with Waikīkī using a five-point Likert scale ranging from “1” meaning very dissatisfied to “3” meaning neutral to “5” meaning very satisfied, and whether box jellyfish impacted their overall satisfaction with the beach using a five-point Likert scale ranging from “1” meaning no impact to “5” meaning major impact.

Participants selected preferred methods for receiving information about box jellyfish from a list of options provided in question #21 (Appendix I). Jellyfish warning signs were not included on the list of dissemination options as these warning signs do not serve to disseminate information but rather to warn beach users about an immediate risk (Figure 1). Perceptions of sign effectiveness were obtained on days when jellyfish warning signs were posted as well as when jellyfish warning signs were not posted. Participants were shown a picture of the jellyfish warning sign or had it described to them verbally when they were not posted.

Ordinal Logistic Regression Model

An ordinal logistic regression model was used to analyze the relationship between various respondent characteristics and ordered responses relative to concern regarding hazards and levels of impact. An ordinal logistic model was originally described by McCullagh (1980) and can be estimated using the R software package “MASS” with the polr() function (Venables & Ripley 2002; R Core Team 2017). This package fits a proportional odds logistic regression model for a dependent response variable between 0 and 1. The proportional odds logistic regression model is defined by Harrell, Jr. (2015) as:

$$\Pr[Y \geq j|X] = \frac{1}{1 + \exp[-(\alpha j + X\beta)]},$$

where Y is the response variable with levels [Y= 0,1,…,*k*] and cutoff values of $j = 1, 2, \ldots, k$. X is each predictor variable, α is the intercept value, and β is the coefficient of the predictor variables. Residuals for the proportional odds model can be defined as:

$$r_{im} = \hat{\beta}_m X_{im} + \frac{[Y_i \geq j] - \hat{P}_{ij}}{\hat{P}_{ij}(1 - \hat{P}_{ij})},$$

where *i* is an individual subject with predictor *m*, and $\hat{P}_{ij}$ is the predicted probability for subject *i* at cutoff *j*. Residuals are used to test the model assumption that a single odds ratio applies equally to all events $Y \geq j, j = 1,2, \ldots, k$. If the assumptions of the model hold, then the odds ratio $X_m + 1 : X_m$ for $Y \geq j$ is $\exp(\beta_m)$ regardless of *j*. The odds ratio can then be interpreted as the change in Y that occurs with an increase in predictor X_m of 1.

In this study, there were 15 dependent response variables included:

- Concern regarding high surf
- Concern regarding water quality
- Concern regarding rocks/coral
- Concern regarding jellyfish
- Concern regarding sharks
- Concern regarding tiger sharks
- Concern regarding nurse sharks
- Concern regarding whitetip reef sharks
- Concern regarding box jellyfish
- Concern regarding blue bottle jellyfish
- Concern regarding moon jellyfish
- Concern regarding jellyfish (after receiving information)
- Concern regarding sharks (after receiving information)
- Impacts to possible revisit to waikīkī
- Impacts to satisfaction with waikīkī

For each of these variables, potential explanatory variables were identified and coded (Table 1) before being used in the polr() function. Independent variables are derived from demographic questions concerning each participant's country of origin, education level, whether they have children with them, consideration for hazards, consideration of safety, planned activities, previous experiences with marine wildlife, opinions of jellyfish warning sign effectiveness, and whether they would change their plans in the event of box jellyfish influx. These factors were used as different experiences, cultures, and backgrounds may shape perception of risks, therefore impacting concern regarding any given hazard (Decker et al. 2010).

Explanatory variables that were significant predictors were placed into a secondary formula that was used to re-estimate the model. The log-likelihood ratio estimated using the lrtest() function in the package "lmtest" was used to test whether the function estimated first with all possible explanatory variables produced a better fit than the second set of explanatory variables (Zeileis & Hothorn 2002). If the difference in log-likelihood is significant, the first estimation fits better than the second.

Relationships between explanatory variables were investigated using the addterm() function in the MASS package (Venables & Ripley 2002) and individual variables were then added one at a time and the log-likelihood ratio was tested comparing the model of reduced second set of explanatory variables and each of the new models. This process was repeated if a new model was determined to be significantly better than a model with fewer explanatory variables ($p - value \leq 0.05$). Odds ratios were then generated using the model found to be the best at explaining the variation in the dependent variable by using the process described above.

Comparisons of Mean Concern

Means of concern levels were compared for general hazards, specific hazardous species, and difference in means for sharks and jellyfish between the 2 parts of the questionnaire. An ANOVA analysis and Tukey HSD were used in R with the provided "stats" package (R Core Team 2017) for comparisons of general hazards and comparisons of specific hazardous species. A one-sided t-test was used to test whether concern regarding jellyfish or sharks decreased after participants were given information on the hazards. For all comparisons, residents and visitors were analyzed separately.

Results

Participant Characteristics

A total of 347 surveys were completed by 123 residents and 223 visitors. Most participating residents lived on O‘ahu and most participating visitors were from the United States, Canada, Europe, and Oceania (Table 2). The mean and median ages of participants was compared to visitor population data (Hawai‘i Tourism Authority Annual Research Report 2016) and resident population data (State of Hawai‘i Data Book 2016). The mean age of participating visitors was 44.1 compared to 44 for the population. The median age of participating residents was 26 compared to 38.6 for the population, therefore the resident participants are younger than the average Oʻahu resident, which may affect the results. Participants engaged in a variety of activities, with most visitors and residents planning to swim and/or lay on the beach (Table 3).

Ordinal Logistic Regression Model

All estimated logistic regression models had different explanatory variables that influenced the fit of each model (Tables 4-6). Regarding initial jellyfish concern, the most influential explanatory variables were jellyfish awareness and consideration of safety. The most influential explanatory variables for post-information jellyfish concern were presence of jellyfish warning signs, consideration of hazards, willingness to change plans, and impact from prior jellyfish experience. Whether a participant was concerned or not about sharks at Waikīkī and willingness to change plans were the most influential explanatory variables that explained increases in the impact of marine wildlife hazard information on a potential revisit to Hawaiʻi. Whether a participant was concerned or not about sharks at Waikīkī codependent with jellyfish awareness was the most influential explanatory variable that explained increases in the impact of marine wildlife hazard information on general satisfaction with Waikīkī. Age was also a significant variable for both models estimating impact of marine wildlife hazard information.

Comparisons of Mean Concern

Mean concern regarding hazards revealed different patterns among residents and visitors. Mean concern was significantly higher for water quality than any other hazard for residents (Figure 3). Mean concern regarding tiger sharks and blue bottle jellyfish were significantly higher than mean concern regarding nurse sharks among residents (Figure 4). There was no significant difference between the sea wasp and any other hazard. Mean concern was significantly higher for water quality hazards than rock/coral hazards among visitors (Figure 3). Mean concern regarding the box jellyfish and the blue bottle jellyfish were significantly higher than concern regarding the nurse shark and there were no other significant differences in concern regarding visitors (Figure 4). When comparing visitor concern levels to resident concern levels, the only significant difference was in concern regarding water quality hazards where resident mean concern was higher than visitor mean concern (Tables 7-8).

A significant decrease in residents' mean concern regarding jellyfish was found between part 1 and part 2 of the questionnaire (Table 9). Additionally, a significant decrease in mean concern regarding sharks between part 1 and part 2 of the questionnaire was found among residents and visitors. In all cases of mean decrease, the mean decrease in concern level was -0.5 points on the Likert scale.

No significant differences in mean beach user enjoyment of Waikīkī were found between beach users that were previously aware of box jellyfish presence and those that were not. Mean impacts of marine wildlife hazard information on a potential revisit were low, at around a Likert score of 2 meaning "unlikely to impact revisit". Mean impacts of marine wildlife hazard information to general satisfaction with Waikīkī were all around a Likert score of 3 meaning "no impact to satisfaction".

Preferred methods for Reception of Information

All participants selected multiple preferred methods for reception of information about hazards. Over half of residents selected social media as a preferred method and over half of visitors selected information panels on the beach as a preferred method (Table 10). Social media and information panels on the beach were both among the top three preferred methods for both visitors and residents.

<u>Discussion</u>

Field survey results support the hypothesis that marine wildlife hazard information would decrease concern regarding those hazards. The mean concern regarding sharks among resident and visitor participants decreased significantly and the mean concern of residents regarding jellyfish decreased significantly. Jellyfish awareness and beach user place of residence were observed to be significant explanatory variables to concern regarding jellyfish at Waikīkī, which supports the hypothesis that these factors would contribute to greater perceptions of risk. Five other factors also contributed to greater concern regarding jellyfish: education level, jellyfish awareness codependent with beach user opinion of warning sign effectiveness, impacts from previous jellyfish experience, consideration of safety, and the length of visit (Table 4). Therefore, future development of educational materials should consider these factors.

The hypothesis that box jellyfish are perceived as a greater risk than all other hazards was not supported because no significant differences between other hazards and box jellyfish were found. However, there were two exceptions found: water quality hazards were perceived as a greater concern than jellyfish hazards for resident participants and box jellyfish were a significantly greater concern than nurse sharks for visitor participants. Marine wildlife hazard information did not impact jellyfish-aware and jellyfish-unaware beach users differently, which does not support the hypothesis that information would have different impacts based on awareness. However, mean Likert scores of impacts to enjoyment of Waikīkī (both to potential revisit and to general satisfaction) were low for all beach users, which suggests that information about marine wildlife hazards will not affect visitation to Waikīkī.

Currently, lifeguards at Waikīkī mitigate box jellyfish stings by removing box jellyfish from the beach and then posting jellyfish warning signs. Despite these clean-up efforts, people entering the water can still be stung during an influx period. Personal observations and interactions with survey participants indicated that at least one person was stung on any given day that box jellyfish were present during the study period. In the case of a sting, lifeguards generally administer a hot-cold pack for the sting or wash the affected area with vinegar. If more than a few people are stung - such as in the February 2016 influx where over 200 people sought medical attention over a 3-day period - lifeguards can be overwhelmed and may call ambulances to provide further assistance (personal communication). The current jellyfish warning signs convey little information about the jellyfish hazard. Some warning signs give written instructions to stay out of the water. Others simply say “Jellyfish” with a drawn image of a generic jellyfish (Figure 1). More detailed information is available through local news outlets and online: details about jellyfish advisories can be found on the Hawai‘i Beach Safety website, calendars are available with predicted dates of influx, and trip advice can be found on a multitude of travel websites. However, this information can be misleading if the wrong image is used, if only a common name is used, or if treatment information is outdated. Accurate information could be vital to someone that is allergic to the sting though it remains out of mind unless they intentionally seek out information beforehand or decide to ask a lifeguard about the warning signs.

An ideal mitigation plan for Waikīkī should involve minimal environmental impact. One environmentally dissociated mitigation plan would be to promote beach user self-regulation, where beach users receive pertinent information that allows them to avoid box jellyfish stings altogether. Understanding the impacts of providing information to the diverse groups of beach users at Waikīkī is important in the interest of maintaining visitor enjoyment. The marine wildlife hazard information provided in this study (Appendix II) had significant impacts on the concern levels of residents and visitors for sharks and jellyfish, indicating that more detailed safety information and recommendations to stay out of the water during jellyfish influx should help to reduce concerns and prevent future stings. Overall, mean scores of impacts to beach user enjoyment regarding Waikīkī revealed that beach users had a mean neutral response towards information about marine wildlife hazards and indicated that the information was unlikely to impact a potential revisit of Hawaiʻi on average. Therefore, providing all the necessary information for beach users to avoid jellyfish stings would likely mitigate stings and help to prevent large scale sting events from occurring. This information would not likely hurt visitor perceptions of the beach itself based on these results and would help to inform visitors to be cautious when warning signs are posted. For residents, the information broadcast through local news could be helpful and a large proportion of residents are aware of the phenomenon. However, not everyone follows traditional news broadcasts.

Providing information through other venues would also likely help many people who do not follow traditional news. In this study, two methods most preferred by both visitors and residents were social media dissemination and placement of information panels on the beach. A Facebook search revealed that the "Waikīkī Beach" page last posted about the jellyfish in March of 2010. Local news outlets also post stories of sting events after influx has occurred. If a social media reminder from one of these pages or a new page managed by an interested group could get information to beach users, then beach users may be better equipped to avoid box jellyfish stings. Having an information panel placed directly on the beach would also ensure everyone at the beach has a chance to receive safety information during their visit. The panels have an additional benefit of potentially reaching every beach user that might encounter a jellyfish by being on site where the hazard can be encountered. Research into an outreach program for educating Hawaiʻi residents about angiostrongyliasis revealed that many dissemination methods are needed to get information to a diverse population of individuals (Dixon, 2013). Therefore, placement of information panels on the beach would likely be the best singular method for educating the greatest number of individuals about marine wildlife hazards at Waikīkī Beach.

Development of educational material for coastal hazards would increase public awareness of hazards issues as well as provide an opportunity to teach visitors about the unique environment of Hawaiʻi. The biology of box jellyfish is unique among jellyfish, and the monthly mass influx of *A. alata* is an ecological phenomenon unique to the south shore of Oʻahu. Little is known about the species overall. Current knowledge includes their monthly appearance, their toxin, and their genome, which provided insight into characteristics of vision, venom, and reproduction (Wiltshire et al. 2000; Chiaverano et al. 2013; Ames et al. 2016). Stings on skin are the primary interaction between beach users and jellyfish. This likely labels the jellyfish purely as an ecosystem disservice for most beach users. Positive aspects of the jellyfish should be explored to appeal to beach users and may serve as an additional draw for visitors. Currently, no known uses for *A. alata* exist, although a recent study by Pedersen et al. (2017) suggests that any jellyfish could be consumed as food using modified traditional cooking techniques from China and Thailand (Hsieh et al. 2001). If this technique were to be tested on *A. alata* then there is a possibility that *A. alata* could become a novelty, local appetizer for visitors to try. In conjunction with outreach and education, the uncharismatic box jellyfish could grab the public's interest, providing a means to educate the public about local ecology and help prevent stings.

Creating an outreach program for box jellyfish hazards is highly relevant to beach users in Hawaiʻi. As most beach users plan to spend time in the water at Waikīkī (Table 3), many people would benefit from receiving information about the box jellyfish influx. As marine wildlife hazard information was unlikely to impact revisits to Waikīkī and mean impacts to general satisfaction with the beach were neutral, evidence indicates that an outreach program designed to raise awareness of jellyfish hazards would not harm tourism or Waikīkī visitation. Over half of the visitors participating in this study were unaware of box jellyfish influx and nearly a third of residents surveyed were also unaware that box jellyfish regularly occur at Waikīkī. Therefore, an outreach program would provide valuable safety information and information on some of the ecology and biology of Waikīkī. Educational material could frame the hazard issue in this ecological context and provide beach users with interesting and useful information regarding the local marine ecosystem, and importantly, the knowledge and means to avoid stings and treat them if necessary.

Chapter 3. Summary and Conclusions

Jellyfish have been reported at Waikīkī Beach for over half a century (Devaney et al. 1977; Crow et al. 2015) and they have been observed at the beach every month since January 1998 (Chiaverano et al. 2013). Jellyfish warning signs were first designed and implemented between 1988 and 1991 with the help of the Waikīkī Aquarium. Since then, these warning signs have been used each time a jellyfish is detected by lifeguards to warn beach users of jellyfish presence. However, 56.3% of visitors and 30.5% of residents were unaware of jellyfish influx when the jellyfish were present at the beach and jellyfish warning signs were posted. Given that most visitors participating in the survey were not aware of the jellyfish, jellyfish warning signs do not appear to be effective at warning beach users of jellyfish presence. Anecdotally, I was asked about the jellyfish warning signs by some participants and I informed them that the jellyfish warning signs only went up when jellyfish were known to be on the beach or in the water, which surprised them. This anecdote reveals that the warning signs may not be expressing all the information that should be communicated to the users of Waikīkī Beach. This is especially true if the visitor has not encountered any information of the jellyfish beforehand.

To reduce injuries from box jellyfish stings, greater public outreach efforts may be needed. Human influences are linked to periodic outbreaks of harmful bacteria at Hawaiian beaches (Oshiro & Fujioka 1995; Fujioka 2001; Cui et al. 2013). Because the problem is sourced from humans, people may be able to improve environmental conditions through funding management. Recent research in Hawaiʻi suggests that beach users would be willing to pay for improvements to beaches, which supports restoration (Penn et al. 2014; Peng & Oleson 2017). For marine wildlife hazards, there is no such vehicle for improving conditions. Encounters with marine wildlife is dependent on the habitat and migrations of marine wildlife species. A shark encounter is very unlikely at Waikīkī, with no encounters currently listed on Hawaiʻi's Division of Aquatic Resources shark incidents list dating back to 1995 (DAR Incidents List), but jellyfish encounters are much more likely as box jellyfish influx occurs every month. In Australia, offshore nets are used to reduce jellyfish and shark encounters (Uninet Enclosure Systems). Costs of nets can be high and require periodic upkeep. There may also be impacts on Hawaiian monk seals or turtles that sometimes swim close to shore. A cost-effective alternative should therefore be considered to prevent injuries due to jellyfish stings at Waikīkī each month.

Results of the public survey indicate that providing marine wildlife hazard information to beach users decreases concern regarding those hazards and does not impact enjoyment of the beach. Therefore, it is recommended that educational materials be developed for informing beach users about box jellyfish influx at Waikīkī. Due to the vast diversity of beach users at this beach, certain beach user characteristics should be considered when developing educational materials, such as whether the beach user is aware of the phenomenon, whether they are local or from abroad, or whether they consider personal safety when going to the beach, among others. Development of this educational material also provides an opportunity to teach beach users about local ecology that they may not otherwise consider. Framing of educational materials through an ecological lens may also raise more interest for the beach than if the materials were framed as a warning. Beach users would benefit from receiving useful information about safety and gaining the opportunity to learn more about a tropical ecosystem that they may not have otherwise.

Tables and Figures

Table 1. Independent variables describing participant characteristics investigated using a proportional odds logistic regression function and the coding used. Responses from survey questions were coded as dummy values to fit the model if necessary. In the case of "Length of Visit", "Willing to Change Plans", "Impact from Jellyfish Experience", and "Impact from Shark Experience", two related questions from the survey were collapsed into one variable.

Explanatory Variable	Coding
Age	Continuous
Children	No=0; Yes=1
Education	Middle School=0; High School=1; Continuing Education=2; Higher Education=3
Origin	No=0; Yes=1
Length of Visit	Continuous
Activities	Out Of Water=0; In Water=1
Consideration of Hazards	No=0; Yes=1
Consideration of Safety	No=0; Yes=1
Willing to Change Plans (Part 2 of Survey)[iii]	No=0; Yes with No Explanation=1; Yes but Stay at Beach=2; Yes and Do Another Activity=3; Yes and Relocate to Another Beach=4; Yes and Return Home or Return to Hotel=5
Jellyfish Awareness[i]	No=0; Yes=1
Impact from Jellyfish Experience[i]	No Experience=0; No Impact=1; Small Impact=2; Moderate Impact=3; Large Impact=4; Major Impact=5
Concern regarding Sharks at Waikīkī[ii]	No=0; Yes=1
Impact from Shark Experience[ii]	No Experience=0; No Impact=1; Small Impact=2; Moderate Impact=3; Large Impact=4; Major Impact=5
Jellyfish Warning Signs Present[ii]	No=0; Yes=1
Jellyfish Signs Effective?[ii]	No=0; Yes=1

[i] Only used for response variables related to jellyfish and impacts

[ii] Only used for response variables related to sharks and impacts

[iii] Only used for response variables in Part 2 of the Survey

Table 2. Island of origin for residents and region of origin for visitors in survey sample.

Place of Residence	Count	Percentage
Residents		
O'ahu	107	87.0
Kaua'i	2	1.6
Maui	9	7.3
Moloka'i	2	1.6
Hawai'i	3	2.4
Visitors		
USA	101	45.1
Canada	37	16.5
Europe	23	10.3
Oceania	47	21.0
Asia	3	1.3
Latin America	3	1.3
N/A	10	4.5

Table 3. Resident and visitor participation in activities. Activities were selected from a list and each participant could select any activities that applied to their current plans. Percentages derived from the number of participants that checked an activity against the total number of participants.

Activity	Resident Participation (%)	Count	Visitor Participation (%)	Count
Swim	83.7	103	84.8	190
Snorkel	36.6	45	44.6	100
Surf	42.3	52	22.3	50
Bodyboard	32.5	40	15.2	34
SCUBA	9.8	12	5.8	13
Stand-up Paddle	29.3	36	15.6	35
Lie on Beach	72.4	89	84.4	189
Other	20.3	25	9.8	22

Table 4. Model results from Proportional Odds Logistic Regression of concern regarding general hazard categories. One asterisk (*) denotes p-value <0.05 and two (**) denotes p-value<0.01. Log likelihood, AIC, and residual deviance values are listed to the right for each model. Model variables were education (E), jellyfish awareness (JA), opinion of sign effectiveness (S), impact of prior jellyfish experience (JI), age (A), origin (O), concern regarding sharks at Waikīkī (SH), consideration of hazards (CH), consideration of safety (CS), and length of visit (LV)

Model		*E*	*E:LV*	*JA*	*JA:S*	*JI*	*A:CS*	*O*	*SH*	*CH*	*CS*	*LV*	*Log Likelihood*	*AIC*	*Residual Deviance*
Concern regarding High Surf	**Coef (SE)**	-	-	-	-	-	-	-	-	0.72** (0.22)	0.80** (0.23)	-	-759.37	1540.74	1518.74
	Odds Ratio	-	-	-	-	-	-	-	-	2.05	2.24	-			
Concern regarding water quality	**Coef (SE)**	-	-	-	-	-	0.03** (4e-3)	0.78** (0.20)	-	-	-	-	-758.21	1539.46	1517.46
	Odds Ratio	-	-	-	-	-	1.03	2.17	-	-	-	-			
Concern regarding jellyfish	**Coef (SE)**	-0.25* (0.11)	-	1.11** (0.34)	-0.69* (0.34)	0.22** (0.08)	-	-0.50* (0.24)	-	-	0.90** (0.21)	-2e-3* (8e-4)	-761.38	1554.77	1522.77
	Odds Ratio	0.78	-	3.02	0.50	1.24	-	0.60	-	-	2.45	1.00			
Concern regarding sharks	**Coef (SE)**	-	-9e-4** (4e-4)	-	-	-	-	-	1.84** (0.22)	-	0.57** (0.20)	-	-732.92	1489.83	1465.83
	Odds Ratio	-	1.00	-	-	-	-	-	6.28	-	1.76	-			
Concern regarding rocks or coral	**Coef (SE)**	-	-	-	-	-	-	-	-	-	0.50* (0.20)	-	-777.53	1578.82	1558.82
	Odds Ratio	-	-	-	-	-	-	-	-	-	1.65	-			

Table 5. Model results from Proportional Odds Logistic Regression of concern regarding species of hazardous marine wildlife. One asterisk (*) denotes p-value <0.05 and two (**) denotes p-value<0.01. Log likelihood, AIC, and residual deviance values are listed to the right for each model. Model variables were education (E), jellyfish awareness (JA), opinion of sign effectiveness (S), impact of prior jellyfish experience (JI), age (A), origin (O), children in party (C), concern regarding sharks at Waikīkī (SH), consideration of hazards (CH), consideration of safety (CS), and length of visit (LV)

Model		*A*	*A:E*	*O*	*O:E*	*S*	*C:JI*	*JA*	*SH*	*CH*	*CS*	*LV*	*Log Likelihood*	*AIC*	*Residual Deviance*
Concern regarding tiger sharks	**Coef (SE)**	-0.03** (0.01)	0.01* (3e-3)	1.38** (0.46)	-0.50** (0.19)	-	-	-	1.49** (0.21)	-	0.74** (0.21)	-2e-3* (8e-4)	-737.27	1506.55	1474.55
	Odds Ratio	0.97	1.01	3.99	0.61	-	-	-	4.43	-	2.09	1.00			
Concern regarding nurse sharks	**Coef (SE)**	-0.01* (0.01)	-	-	-	-	-	-	q1.34** (0.21)	-	0.46* (0.21)	-2e-3* (8e-4)	-711.05	1448.11	1422.11
	Odds Ratio	0.99	-	-	-	-	-	-	3.83	-	1.58	1.00			
Concern regarding whitetip reef sharks	**Coef (SE)**	-0.01 (0.01)	-	-	-	-	-	-	1.34** (0.21)	0.52** (0.20)	-	-2e-3* (8e-4)	-729.50	1485.01	1459.01
	Odds Ratio	0.99	-	-	-	-	-	-	3.82	1.68	-	1.00			
Concern regarding box jellyfish	**Coef (SE)**	-	-	-	-0.30** (0.10)	0.74** (0.19)	0.25* (0.12)	0.61** (0.21)	-	0.48* (0.22)	0.57* (0.24)	-	-759.67	1549.35	1519.35
	Odds Ratio	-	-	-	0.74	2.10	1.28	1.84	-	1.62	1.77	-			
Concern regarding blue bottle jellyfish	**Coef (SE)**	-	-	-	-	0.51** (0.19)	0.29* (0.12)	-	-	0.87** (0.19)	-	-	-777.46	1578.93	1554.93
	Odds Ratio	-	-	-	-	1.67	1.34	-	-	2.38	-	-			
Concern regarding moon jellyfish	**Coef (SE)**	-	-	-	-0.36** (0.10)	0.48* (0.19)	-	0.49* (0.20)	-	-	0.90** (0.21)	-	-759.04	1544.09	1518.09
	Odds Ratio	-	-	-	0.70	1.62	-	1.63	-	-	2.45	-			

Table 6. Model results from Proportional Odds Logistic Regression of variables related to questions in the survey that relied on marine wildlife hazard information (Appendix II). One asterisk (*) denotes p-value <0.05 and two (**) denotes p-value<0.01. Log likelihood, AIC, and residual deviance values are listed to the right for each model. Model variables were education (E), activities (AC), jellyfish awareness (JA), opinion of sign effectiveness (S), impact of prior jellyfish experience (JI), impact of prior shark experience (SI), age (A), origin (O), children in party (C), willingness to change plans (WC), concern regarding sharks at Waikīkī (SH), consideration of hazards (CH), and length of visit (LV)

Model		*A*	*E*	*AC*	*WC*	*O*	*O:SH*	*O:SI*	*O:AC*	*S*	*JI*	*SH*	*JA:SH*	*CH*	*LV:C*	*Log Likelihood*	*AIC*	*Residual Deviance*
Concern regarding jellyfish (After information)	**Coef (SE)**	-	-0.31** (0.11)	-1.05** (0.37)	0.26** (0.07)	-0.95** (0.22)	-	-	-	0.46* (0.20)	0.22** (0.08)	-	-	0.60** (0.20)	-	-752.07	1536.15	1504.15
	Odds Ratio	-	0.74	0.35	1.30	0.39	-	-	-	1.59	1.25	-	-	1.82	-			
Concern regarding sharks (After information)	**Coef (SE)**	-	-	-	-	-1.20** (0.30)	1.02* (0.43)	0.42** (0.13)	-	-	-	1.50** (0.25)	-	-	-			
	Odds Ratio	-	-	-	-	0.30	2.77	1.53	-	-	-	4.48	-	-	-			
Impact of information on potential revisit	**Coef (SE)**	-0.02* (0.01)	-	-	0.19* (0.07)	-2.12* (0.86)	-	-	1.63 (0.86)	-	-	0.63** (0.22)	-	-	-0.01 (0.01)	-451.50	923.01	903.01
	Odds Ratio	0.98	-	-	1.21	0.12	-	-	5.10	-		1.88	-	-	0.99			
Impact of information on overall satisfaction	**Coef (SE)**	0.02* (0.01)	-	-	-	-	-	-	-	-	-	-	0.65* (0.30)	-	-	-344.65	701.31	689.31
	Odds Ratio	1.02	-	-	-	-	-	-	-	-	-	-	1.92	-	-			

Table 7. Mean concern of provided general hazards reported by residents and visitors of Waikīkī Beach. P-values obtained from student's t-test comparing resident mean and visitor mean. (*) denotes significance of $p \leq 0.05$.

Hazard	Resident mean	Visitor mean	p-value
High Surf	4.17	4.53	0.2955
Water Quality	5.77	5.01	0.0186*
Sharks	3.98	4.49	0.1494
Jellyfish	4.04	4.54	0.1216
Rocks/Coral	3.87	3.89	0.9509

Table 8. Mean concern of provided hazardous species reported by residents and visitors of Waikīkī Beach. P-values obtained from student's t-test comparing resident mean and visitor mean.

Species	Common Name	Resident mean	Visitor mean	p-value
Galeocerdo cuvier	Tiger Shark	4.38	4.07	0.3640
Ginglymostoma cirratum	Nurse Shark	3.01	3.40	0.2512
Traenodon obesus	Whitetip Reef Shark	3.28	3.63	0.3141
Alatina alata	Box Jellyfish or Sea Wasp	4.11	4.28	0.5883
Physalia utriculus	Portugeuse Man-o-war or Bluebottle	4.32	4.33	0.9794
Aurelia aurita	Moon Jellyfish	3.49	3.96	0.1666

Table 9. Change in concern for jellyfish and sharks comparing responses between part 1 and part 2 of the questionnaire. Mean difference calculated from differences of concern before and after for each participant. Negative values signify a decrease in concern, and positive values signify an increase in level of concern. P-values observed from a one-sided, one-sample t-test.

Jellyfish			
Origin	**Mean Difference**	**p**	**n**
Resident	-0.49	0.027*	123
Visitor	+0.22	0.552	224
Sharks			
Origin	**Mean Difference**	**p**	**n**
Resident	-0.55	0.004*	123
Visitor	-0.50	0.002*	224

Table 10. Preferred dissemination methods as described by participants. Selection of multiple options was allowed per participant. Percentage reflects the fraction of participants that selected an option out of total participants .

Origin	Dissemination Method	n	%
Resident	TV News	45	36.6
	Website	15	12.2
	Social Media	63	51.2
	Brochures in Hotels/Airport	16	13.0
	Posters in Hotels/Airport	30	24.4
	Information Desk	15	12.2
	Info Panels on Beach	51	41.5
	Other	5	4.1
Visitor	TV News	48	21.4
	Website	32	14.3
	Social Media	68	30.4
	Brochures in Hotels/Airport	63	28.1
	Posters in Hotels/Airport	70	31.2
	Information Desk	39	17.4
	Info Panels on Beach	119	53.1
	Other	7	3.1

Figure 1. Current signs posted when jellyfish are present at the beach on Oʻahu. Multiple signs are posted along the shoreline at approximately equal distances.

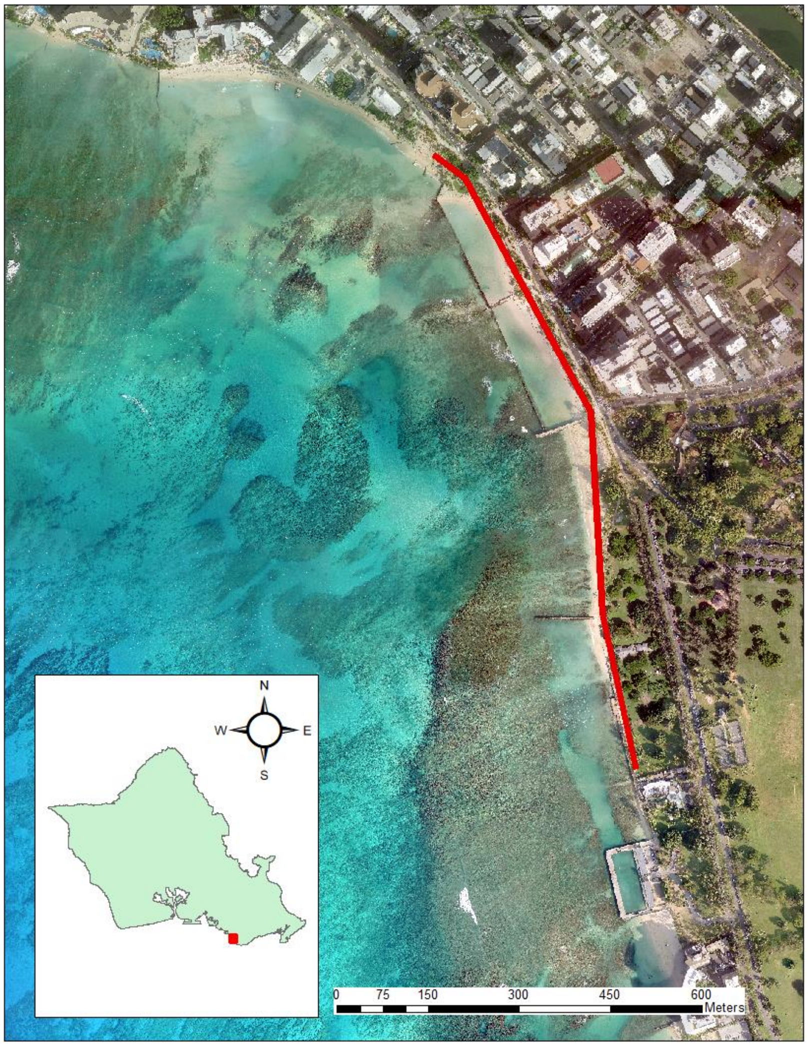


Figure 2. Map of survey area at Waikīkī between lifeguard towers 2B and 2F. Total length of beach shown is 1100 meters, indicated by the red line. Satellite Imagery obtained from USGS Earth Explorer. Images produced by Dewberry and Davis, LLC. This is the same site used by Chiaverano et al. (2013).

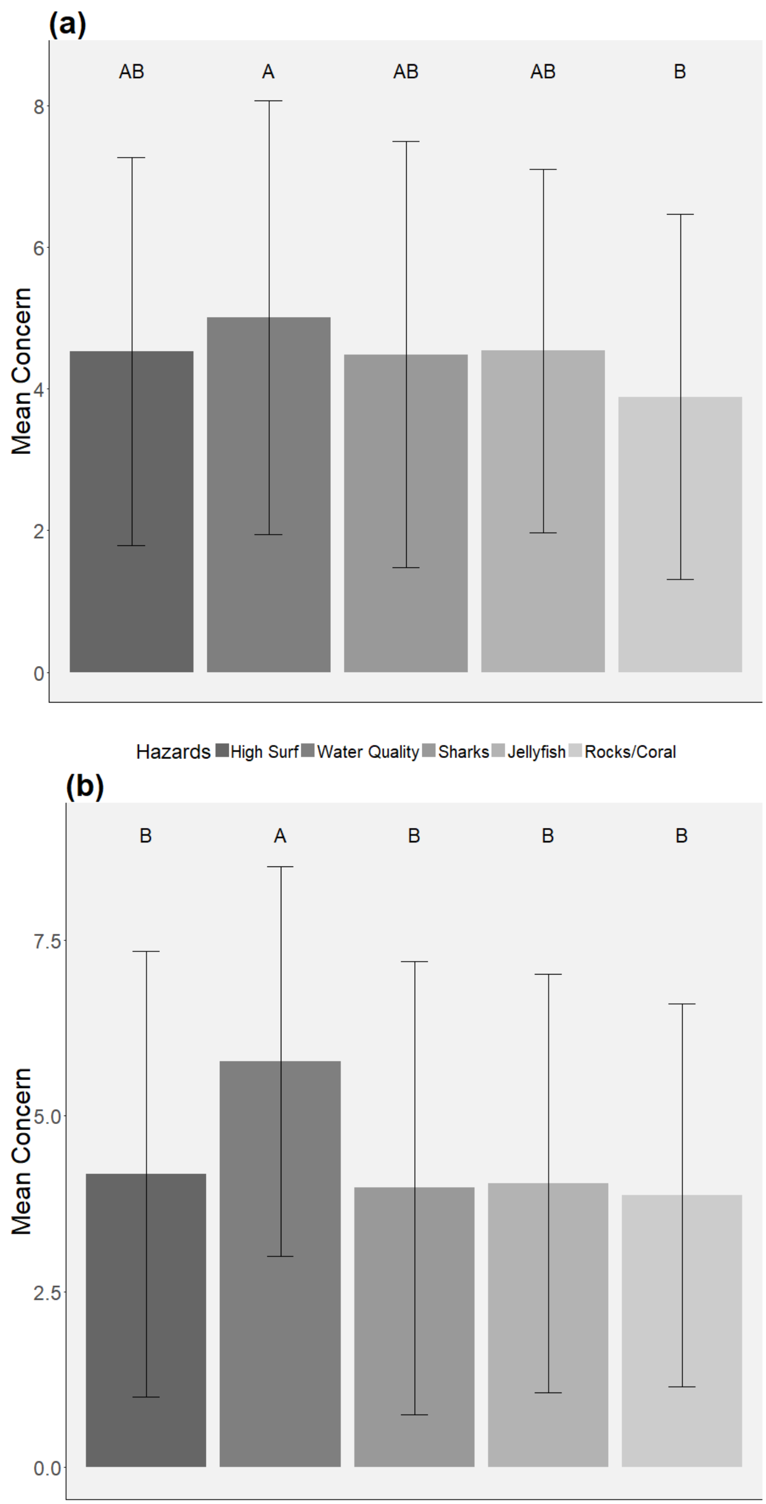


Figure 3. Mean concern scores for (a) visitors and (b) residents regarding general hazards at the beach. Error bars represent standard deviation. Letters above bars denote significant differences in concern levels.

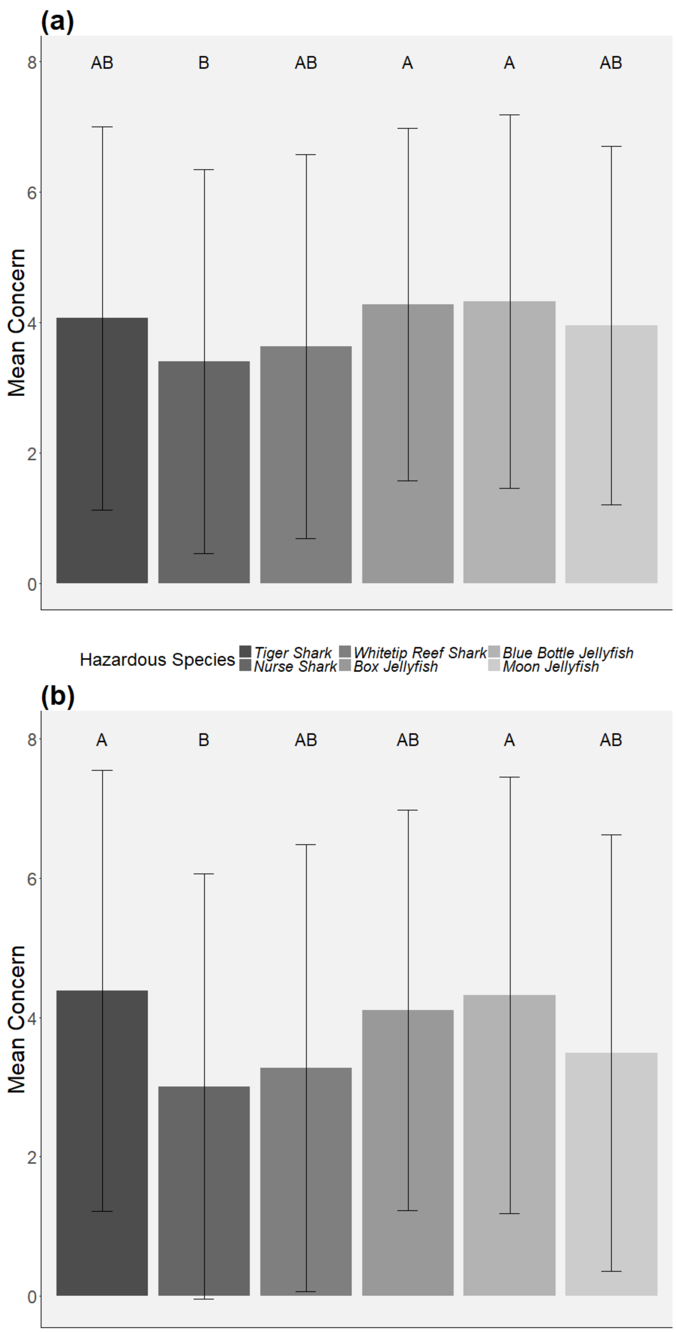


Figure 4. Mean concern scores of (a) visitors and (b) residents regarding hazardous marine species provided in Waikīkī survey. Error bars represent standard deviation. Letters above bars denote significant differences in concern levels.

Appendix A: Waikīkī Wildlife Hazard Survey

Waikiki Wildlife Hazard Survey Part 1

1. In what year were you born? _____________
2. Do you have children with you? ❍ Yes ❍ No
3. What is your highest level of education?

   ❍ Graduate (PhD, MS, MBa, etc) ❍ Associates degree
   ❍ 4-year university ❍ High school Diploma
   ❍ Professional school ❍ Other:_________
4. Are you a Hawaii resident or visitor? ❍ Resident ❍ Visitor
   i. (Residents) What is your island of residence? ______________________
   ii. (Visitors) What is your country of origin? ______________________
5. (Visitors) How long are you visiting Oʻahu? _________________
6. (Residents) How many times per year do you visit Waikiki? __________________
7. What activities will you be doing on the beach? Check all that apply:

   ❍ Swimming ❍ Body/Boogie Boarding ❍ Lay on the beach
   ❍ Snorkeling ❍ SCUBA Diving ❍ Other:
   ❍ Surfing ❍ Paddleboarding ______________
8. Do you consider potential hazards in your decision to go to the beach? ❍ Yes ❍ No
9. Do you consider any of the following when making your decision (Check all that apply)?

   ❍ Safety ❍ Time investment
   ❍ Property security ❍ Access to facilities
10. How concerned or unconcerned are you about the following animals or conditions at the beach?

Type of Hazard	No concern				Some concern					Very concerned
	0	1	2	3	4	5	6	7	8	9
High surf/strong currents	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Poor water quality	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Sharks	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Jellyfish	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Rocks/Coral reef	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

11. How concerned or unconcerned are you about the following coastal species in HI?

	No concern				Some concern					Very concerned
	0	1	2	3	4	5	6	7	8	9
Tiger sharks (*Galeocerdo cuvier)*	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Nurse sharks (*Ginglymostoma cirratum)*	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Whitetip reef sharks (*Triaenodon obesus*)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Sea wasp/box jellyfish (*Alatina alata*)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Blue bottle/man-o-war (*Physalia utriculus*)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Moon jellyfish (*Aurelia aurita*)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

12. Are you aware that jellyfish regularly occur on or near the beach at Waikiki and Ala Moana? ❍ Yes ❍ No
    i. If yes, how did you learn about this phenomenon? ________________________

    ____

13. Have you or anyone you know been stung by a jellyfish before? ❍ Yes ❍ No
    i. If yes, how did this impact your decisions to visit beaches?

❍ No impact ❍ Small impact ❍ Moderate impact ❍ Large impact ❍ Major impact

14. Are you concerned about shark sightings at this beach? ❍ Yes ❍ No
15. Have you or anyone you know encountered a shark before? ❍ Yes ❍ No
    i. If yes, how did this impact your decisions to visit beaches?

❍ No impact ❍ Small impact ❍ Moderate impact ❍ Large impact ❍ Major impact

Please return this part of the survey before continuing

Waikiki Wildlife Hazard Survey Part 2

16. How concerned or unconcerned are you about the box jellyfish in Hawaii now that you know more about them on a scale of 0-9?

❍ 0 ❍ 1 ❍ 2 ❍ 3 ❍ 4 ❍ 5 ❍ 6 ❍ 7 ❍ 8 ❍ 9

17. How concerned or unconcerned are you about sharks in Hawaii now that you know more about them?

❍ 0 ❍ 1 ❍ 2 ❍ 3 ❍ 4 ❍ 5 ❍ 6 ❍ 7 ❍ 8 ❍ 9

18. Do you think the current signage is effective? ❍ Yes ❍ No

19. If you saw warning signs on the beach, would this change your daily plans?
    ❍ Yes ❍ No
    i. If yes, would you:

    ❍ Relocate to another beach ❍ Stay, but keep out of water

    ❍ Do another activity ❍ Return home or to hotel

20. How likely is it that this information will impact your decision to return to Waikiki?

❍ Very Unlikely ❍ Unlikely ❍ Neutral ❍ Likely ❍ Very Likely

21. What do you think the best way to provide information might be? Choose one:

    ❍ TV News ❍ Posters in Hotels/Airport

    ❍ Website ❍ Information Desk

    ❍ Social Media ❍ Info Panels on Beach

    ❍ Brochures in Hotels/Airport ❍ Other: ________________

22. What is your level of satisfaction with Waikiki Beach?
    ❍ Very Dissatisfied ❍ Dissatisfied ❍ Neutral ❍ Satisfied ❍ Very Satisfied

23. How does knowledge of sharks and box jellyfish affect your satisfaction with Waikiki Beach, if at all?
    ❍ Very Negatively ❍ Negatively ❍ No Impact ❍ Positively ❍ Very Positively

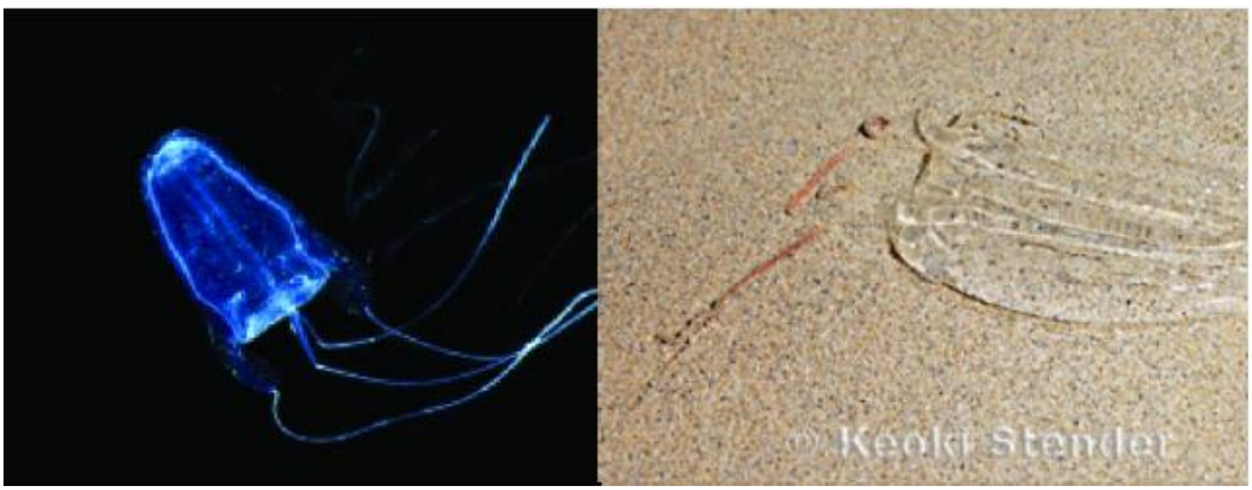
Appendix B: Marine Wildlife Hazard Information Card

Front

Box jellyfish arrive during the evening every month from 8 to 12 days after a full moon and can be sighted during each day of this period. Box jellyfish are known to sting people if unprotected skin comes in contact with the tentacles. The local species is known as *Alatina alata*. The sting from this species in Hawaii is non-lethal and about the same intensity as a bee sting. There have been cases where people had an allergic reaction and were sent to the emergency room. However, there have been no reported deaths from a box jellyfish sting in Hawaii. Stings can easily be avoided by staying out of the water when warning signs are posted on the beach.

In comparison, sharks have been reported at Waikiki much less frequently. Across Oahu, Sharks are more likely to be seen during the summer and early winter. If a shark is sighted and signs are up, you are advised to stay out of the water.

Back



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