

Are warning signs effective in communicating jellyfish hazards?

Abstract

Warning signs are widely used at beach environments to improve safety by alerting visitors to dangerous jellyfish hazards. Empirical data describing beachgoers interpretation of beach warnings is scarce. This study aims to assess the visibility, interpretation and effectiveness of two warning signs in communicating jellyfish hazards to beachgoers at two beaches, one in Australia and one in the USA. Both signs were measured against industry standards and research based design guidelines for effective warnings. Results of the study found that while the US sign meets all such standards, Australia's sign does not. Of the 214 beachgoers interviewed, a higher number of respondents accurately described the meaning of the US sign than the Australian sign. However, interpretation depends on visibility of the sign which was found to be better in the Australian context. Tourists in Australia were found to be least informed of the jellyfish hazard, particularly inside stinger resistant enclosures. This study's results suggest that the signage could be improved in both locations.

Keywords: Warnings, Risk Communication, Jellyfish, Beach Safety

Introduction

In Australia and Hawaii, jellyfish pose a risk to the health of beachgoers. In Australia, the large box jellyfish (*Chironex fleckeri*) and tiny Irukandji jellyfish (*Carukia barnes*) are known as 'marine stingers'.¹ These jellyfish are deadly and ranked amongst the world's most dangerous animals.² In Hawaii, the jellyfish (*Carybdea alata*) is considered dangerous but not deadly.³ In Australia's tropical regions, stinger resistant enclosures ("stinger nets") provide a swimming site that protects beachgoers against box jellyfish but not against Irukandji jellyfish that can swim through the mesh of the nets.⁴ Beachgoers are encouraged by beach authorities to remain inside the nets when entering the water and to wear "Lycra and neoprene suits" as additional protection from stings.^{5,6}

In Queensland alone, an estimated 200 people are said to be hospitalised annually following an Irukandji sting, with an accompanying treatment cost of around \$10-14 million.⁷ As in Australia, jellyfish stings are also on the rise at popular tourist beaches in Hawaii.⁸ At both beaches in this study, lifeguards, first aid stations and beach safety campaigns (supported

online and in the media) are present during jellyfish season. There is currently no antivenin to treat sting injuries.

According to beach authorities, jellyfish warning signs are the most cost effective means of informing, reminding and warning beachgoers of the jellyfish hazard and, in so doing, they bring foreseeable risks to people's attention so that they can make informed decisions about entering the ocean.⁵ Research studies confirm that a well-designed warning sign can motivate readers to think and care about their personal safety and the safety of those in their care by influencing decisions about risks.^{9,10} Research studies have also found that to be effective, warning signs must be noticed, identify the hazard, explain the consequences of exposure to the hazard and encourage behaviours that may reduce risk of injury or death.¹¹ These components are also outlined, for example, in the US standard ANSI Z535.4 (2011).¹² Wogalter¹⁰ provides a detailed summary of these components as design guidelines for warning signs that include testing signage interpretation to verify how well the sign works.

To improve noticeability and alert readers of the hazard, design guidelines refer to a signal word panel containing the word "WARNING" in large text indicating a "potential hazardous situation that may result in death or serious injury if not avoided".¹³ Shapes and colours also have an alerting function. The international standard ISO 3864-1 (2011)¹⁴ and US standard ANSI Z353.3 (2011)¹⁵ provide design rules for shapes and colours of safety related symbol signs. A black symbol or pictogram on a yellow diamond shaped sign with black borders defines a colour and shape combination that is understood in Australia, the US and most other parts of the world as providing a warning.¹⁶ The physical location of the sign, its size, and the use of appropriate text and symbols has also been found to impact on its effectiveness and noticeability.^{18,19}

In stimuli rich environments, the location of warnings can be a significant factor in their noticeability.²⁰ For example, beach warning studies have found that only around half of the people who pass signs will notice them. In the US, a study of 392 beach users at three heavily frequented public beaches in Texas at the height of summer found 52% of the people interviewed had noticed any warning signs about rips.²¹ In Australia, a study of 472 beachgoers across 4 different beaches found only 45% of respondents observed any signage.¹⁶ Signs depicting hazard symbols were found to be most noticed but this did not necessarily translate into specific knowledge of the beach hazard or have an immediate effect on beachgoers.^{16,22} According to Wogalter, DeJoy and Laughery,²³ change in behaviour can depend on sign

comprehension, the expectation of the reader with regards to the outcome of adhering to the sign, and a cost/benefit analysis undergone by the reader.

Information on a particular hazard, its consequences and how to avoid it, can all be transmitted through appropriate text, but the challenge is to remain sufficiently brief so that the sign is likely to be read.²⁴ Signs that contain lengthy text can be problematic if the warning has to be communicated in several languages,¹⁶ for example, or they are located in stimuli rich environments like beaches, where high temperatures in summer may quickly result in a loss of interest in reading signs. Pictograms or symbols can assist in communicating risk by putting lengthy or unfamiliar text into a more meaningful context. Well-designed pictograms or symbols have been found in road sign studies to increase the likelihood that warnings will be seen and remembered.^{25,26} If symbols are unclear, difficult to decode, or do not relate to the content of the message, warnings may be misconstrued or ignored.

How beachgoers are interpreting jellyfish warning signs in the field is unknown. Despite considerable research into safety and risk communication through signage in general, very little has focused on specifics of jellyfish warning signs. A major reason for this lack of evidence is that warning signs, in general, are rarely evaluated in the context of actual use.¹⁶ This is despite the level of danger or health hazard presented by the jellyfish. For instance, to date only one study in 2004 has found that there is a general lack of knowledge (particularly by tourists) about the Irukandji and the danger it presents inside stinger nets.²⁷ The study found that of the 208 beach users interviewed while travelling on a ferry to Magnetic Island, many of the local residents were aware of the Irukandji health hazard, but only half (51%) of the tourists interviewed knew what an Irukandji was, with international tourists the least knowledgeable. When questioned about stinger nets, 50% of the international tourists, 20% of the domestic tourists and 4% of the locals assumed the nets provided safe places to swim. This further suggests that research into how beachgoers, tourists in particular, are interpreting Australia's marine stinger warning sign at netted beaches is warranted.

In terms of local residents, a 2010 study that reviewed medical data collected at two large regional hospitals in North Queensland, found that almost half (44%) of patients admitted with Irukandji sting injuries were locals.²⁸ This suggests that even where local beachgoers are most exposed to information about the Irukandji risk, some may not notice the warnings or do not know or fully appreciate the full safety message. Alternatively, some may simply be choosing to disregard the warnings.

A growing body of warning research reinforces the need to carry out some sort of testing to evaluate the continued impact of warnings on audiences in the field.¹⁰ Field evaluation of behavioural compliance with jellyfish warning signs allows for the signs effectiveness to be tested and modified if needed.²⁹ Ongoing reports of jellyfish sting injuries at both beaches in this study indicate that the warning signs may not be effectively communicating the jellyfish hazard. Getting feedback from beachgoers is the first step in determining whether or not the signs are being seen and interpreted as intended.

In this study, industry standards and research based design guidelines for effective communication provide the basis for the review of the design of both signs and their modifications. The aim of this study is to assess the communication effectiveness of the jellyfish warning signs used at two popular tourist beaches, one in Australia, and one in Hawaii. This study was designed to extend the evidence on the effectiveness of beach warning signs in communicating hazards to visitors by the following questions:

1. Do beachgoers who pass a marine stinger or jellyfish warning sign at high volume tourist beaches notice the sign?
2. Once the sign is read, do beachgoers become more aware of the hazard at that beach?
3. To what extent does the sign influence their water activities in response to the hazard?

Study Methods

The qualitative study design adopted involves an exploratory, descriptive approach to data collection, and a generative thematic approach to data analysis, reflecting the aim of gaining a deeper understanding of beachgoers interpretation of jellyfish warning signs.³⁰ The main factors were high volume tourist beaches, annual sting injuries and the presence of jellyfish warning signs.

Face to face interviews were conducted with respondents based on a pre-developed questionnaire. The interviewer recorded the responses in writing and by audio-recording later transcribed verbatim for analysis.

The beach environments and signs were assessed to allow observation of the signs by respondents based on a permissible viewing distance of within 5 metres from the sign.

Interviews took place within the beach swimming area to allow for people who intend to enter the water to be interviewed. Placement of beach safety signs is undertaken by lifeguards and lifesavers. The signs were assessed for compatibility with relevant water safety standards for effective warning signs and appropriate placement.^{31,32} Specifically, which and how many of the following standards were met: shape and colour combinations, noticeability, the inclusion of an alert panel and word, the use of text and symbols to inform of the hazard, its consequences and how to avoid it.

Respondents identified for interview were drawn from people present at two beach locations, Palm Cove beach on Australia's Great Barrier Reef coastline and Waikiki beach in Hawaii at the height of summer when jellyfish are expected to be present.^{33,34} Interviews were conducted between 10am and 4pm (when most water activities took place) over four days: December 24-27, 2013 at Palm Cove and December 2-5, 2015 at Waikiki. A total of 113 interviews were conducted at Palm Cove beach and 111 at Waikiki beach representing a response rate of 96.4% and 94.6% of those approached. Interviews that produced conflicting comments and undecipherable responses were removed during data analysis leaving a total of 214 respondents (109 at Palm Cove and 105 at Waikiki).

A purposive sampling technique was used to invite respondents of at least 18 years and over to participate in a five minute interview. Respondents were asked to select an age range based on the standard ten year age groups commencing with 18-29 years as recommended by the Australian Bureau of Statistics.³⁵ Respondents were selected to represent diversity among beachgoers. The next nearest person to the interviewer was selected after each previous interview was completed. Where possible, alternate genders were targeted to maximize variation in the sampling. To avoid bias, respondents in groups or pairs were interviewed separately. If respondents preferred not to separate, only one person was interviewed. If any person did not agree to be interviewed, the interviewer thanked them and moved on. The purposive sampling process did not produce statistically representative samples; rather, it generated sample groups that included the range of opinion that exists within the broader population of beachgoers within those groups.³⁰ The purposive process allowed the capture of primary data about the meaning of specific signs warning of a hazard to which the groups were exposed.

Interview data was aggregated into predefined mutually exclusive and collectively exhaustive groups in two ways, by residential location (local, national tourist, international

tourist) and frequency of beach visitation (first time; occasional: 2-3 times; 4 or more times).³⁶ Locals were identified as those that had resided in the local area (coastline from Palm Cove to the Whitsundays where marine stingers, signs and nets are present, or Hawaii) for at least a year. There is an expectation that locals have a greater awareness of local beach environments and knowledge of the jellyfish hazard.²⁷ The period of at least a year would increase the likelihood of exposure to the jellyfish warning signs, safety messages and campaigns during stinger season in North Queensland and full moon cycles in Hawaii during summer. There is a similar expectation of increasing familiarity by tourists based on their return visits. Respondents were aggregated into three groups based on their residential status and beach visitation to provide a point of comparison to test whether awareness of the jellyfish hazard was greater amongst the locals and whether awareness increased with repeat beach visits.

Analytic strategy

Chi-square tests were undertaken to identify possible relationships between the two variables, sign observation and whether the beach had been visited before and differences in sample characteristics between groups. The interviews were analysed using a generative thematic approach, aided by qualitative analysis software SPSS Version 23 and reported by descriptive statistics. Interview data was analysed to explore the respondents' interpretation of the signs and their perception of danger in entering the water. Thematic analysis of the interviews was conducted by a research assistant to identify emerging themes and sub-themes based on the language used by the respondents.³⁷ One in three interviews were analysed independently by the author to provide reliability for the themes identified. The verified themes were used to code each transcript, identifying relevant statements made by respondents under the thematic headings.

Ethics approval for this study was obtained from the University of Southern Queensland Human Research Ethics Committee before the study commenced (approval number H13REA255).

Questionnaire

There were a total of 6 questions in the questionnaire. Four questions were used to characterise the sample and 2 questions were used to determine what respondents learnt about the hazard from the relevant warning sign. Information about age, gender, residential location,

beach visitation and sign observation were collected. Sign observation was assessed by asking whether respondents had seen the relevant warning sign as they approached the beach that day. Responses to this question were recorded as “yes” or “no”. All respondents were then shown an A4 computer printed colour photograph of the relevant sign. Those who answered yes to having seen the sign, were then asked to confirm it matched the sign in the photograph.

Respondents were then asked two open-ended questions to determine what respondents had learnt about the hazard from the sign. The first question, “What do you think people might think the sign means?” was worded indirectly to improve accuracy by lowering the inclination of providing “right” answers.³⁸ The second open-ended question, “Is there anywhere on this beach where you would swim or go into the water?” was designed to investigate whether reading the sign influences water activities. Open-ended questions allowed in-depth information pertaining to respondents’ experiences and viewpoints of the meaning of the sign to be captured.

Results

Signage

Australia and Hawaii adopted appropriate composite signs for temporary beach conditions according to international standard ISO 20712-3 (2008). Jellyfish warning signs were present along the shoreline of both beaches. At Palm Cove beach, there were also marine stinger warning signs positioned next to the stinger net entrances and safety flags. Outside the stinger net area, “No Swimming” pictogram signs appeared at intervals along the length of the beach. There were no stinger nets or “No Swimming” signs present at Waikiki beach.

At both beaches, the warning signs were attached to metal poles typically with a yellow or red flag at the top of the pole. They were single standard composite signs consisting of a yellow diamond with a black border, a symbol and text in black as shown in Figs 1 and 2. When measured against effective warning design guidelines, the Australian warning sign met only two, the US standard colour and shape combination and hazard text “MARINE STINGERS” with an accompanying jellyfish symbol. The US sign met all of the warning design guidelines including colour and shape combination, an alert panel with the word “WARNING”, the hazard “JELLYFISH” in large text and accompanying pictogram showing

jellyfish symbols underwater around the legs of a person symbol. Additional text includes the consequences of the hazard “Stings can be painful” and how to avoid it “Stay out of the water”.



Fig. 1. Photograph of marine stinger warning sign shown to Palm Cove participants



Fig. 2. Photograph of jellyfish warning sign shown to Waikiki participants

Sample Characteristics

Overall, 85% of respondents in this study were tourists (75% of Palm Cove and 94% of Waikiki respondents). International tourists made up the largest group (43% of Palm Cove and 68% of Waikiki respondents) and locals made up the smallest group (25% of Palm Cove and 6% of Waikiki respondents).

Table 1 shows the total number of respondents broken down by age, gender, beach visits, and sign observation. When compared, the results indicate Palm Cove respondents were younger with the highest percentage (43%) falling within the 18-29 age range, whereas the highest percentage of Waikiki respondents (36%) fell within the 50-69 age range. In terms of gender, more females were interviewed at Waikiki (66%) than at Palm Cove where results indicate a more even distribution (49% female and 51% male).

Table 1. Sample Characteristics of age, gender, beach visitation and signage observation: Sample (N=109 Palm Cove; (N=105) Waikiki

Sample Characteristics	Palm Cove	Waikiki
Age		
18-29	47	34
30-49	35	26
50-69	20	38
70 and over	7	7
Gender		
Female	53	69
Male	56	36
Beach Visits		
First time	66	55
Occasional (2-3 times)	21	22
Regular (4 or more)	21	28
Sign Observation		
Saw sign	87	19
Did not see sign	22	86

In terms of beach visitation, over 50% of respondents at both locations (61% Palm Cove and 52% Waikiki) were first time visitors with international tourists (38% Palm Cove and 37% Waikiki) representing the largest group. One Palm Cove respondent did not provide a response.

The remainder of respondents indicated occasional (2 to 3 times) and regular (4 or more times) visits to the beach locations.

In terms of signage observation, a much higher percentage of Palm Cove respondents 80% (74% locals, 71% national tourists and 89% international tourists) reported noticing the marine stinger warning sign than Waikiki respondents. Only 18% (33% of locals, 18% of national tourists and 17% of the international tourists) of Waikiki respondents reported noticing the jellyfish warning sign at the beach that day. All of these respondents, 87 at Palm Cove and 19 at Waikiki beach, confirmed their response when shown a photo of the relevant sign.

There was no significant association in any of the groups with regards to age or gender in terms of noticing the signs.

Signage interpretation

As shown in Table 2, two dominant themes emerged, jellyfish danger and sign design, related to the question “What do you think people might think the sign means?”

Table 2. Categories of comments by respondents on signage interpretation and water safety questions

Sample: Palm Cove Locals (N=26), National tourists (N=32), International tourists (N=38); (N=103) Waikiki Locals (N=6), National tourists (N=28), International tourists (N=69).

	Local Residents		National Tourists		International Tourists	
Categories	Palm Cove	Waikiki	Palm Cove	Waikiki	Palm Cove	Waikiki

Question: “What do you think people might think the sign means?”

Jellyfish Danger

Jellyfish identification

Correct	24	6	29	28	31	68
Incorrect	1	0	0	0	5	1

Danger in water

	17	3	23	25	30	83
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Warning sign

	7	1	7	11	9	12
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Question: “Is there anywhere at this beach where you would swim or enter the water?” Sample: (N=109) Palm Cove; (N=105) Waikiki.

Water Safety

Safe to enter the water	17	5	27	15	39	30
Not safe to enter the water	10	1	8	13	8	41

Many respondents provided more than one comment in their responses to the questions. Therefore, more responses have been captured than there are respondents and totals have not been provided.

In regards to the first theme, jellyfish danger, three sub-themes emerged: jellyfish identification, danger in the water, and warning sign. The first sub-theme is that the sign represents a jellyfish. Most of the 90 comments by Palm Cove respondents describing the sign as referring to a marine creature, correctly identified the symbol as “a picture” of a “jellyfish” or a “stinger”. Tourists, mainly those from overseas, were least able to identify the symbol as a jellyfish. For example, there were 6 comments (5 by international tourists) that incorrectly interpreted the symbol as an “octopus”, “stingray”, “bee or wasp”. A further 11 comments by tourists identified the symbol as a “box jellyfish” indicating that the symbol was not understood as representing the Irukandji. This is important because the intention of the sign is to warn of “marine stinger” hazards which includes both the box jellyfish and the Irukandji despite only one symbol appearing on the sign which is devoid of scale to indicate the size difference or that there are two marine stingers. When compared to Waikiki results, there were 103 comments by respondents that correctly described the sign as referring to “jellyfish” with 51 comments including “in the water” or “sea”. It is unclear whether the responses were based on

the symbol, the sign or both combined as the word “jellyfish” is present as part of the sign’s text. One tourist from Australia identified the sign as referring to “marine stingers” which was also considered correct. Only one international tourist incorrectly stated “some kind of fish” suggesting that the sign is effective in communicating the hazard.

The second sub-theme that emerged as part of jellyfish danger, is that it is dangerous in the water. There were 56 comments by Palm Cove respondents (57% by locals, 50% by national tourists, 66% by international tourists) that described the sign as indicating that swimming or entering the water was not safe (e.g. “Don’t go into the ocean”, “Don’t go outside nets”). An additional 14 comments described some potential for harm to people (e.g. “Things can bite you”, “Box jellyfish can sting”). In comparison, there were considerably fewer comments made indicating a perception of danger in the water by Waikiki respondents. For example, there were 21 comments by Waikiki respondents (17% by locals, 14% by national tourists and 23% by international tourists) that described swimming or entering the water as dangerous (e.g. “It’s not safe to swim”, “don’t go in the water”) and a further 83 comments describing some potential for harm to people (“they sting and hurt”; “I know they bite”; “they inject poison”). The results again suggest that international tourists are more likely to interpret the danger message from both the signs.

A final sub-theme relating to jellyfish danger, was a perception that the sign acted as a warning. A similar number of comments by respondents at both beach locations (23 Palm Cove, 24 Waikiki) correctly described the sign as a warning or alert of danger.

In terms of the second dominant theme identified, sign design, respondents spoke about different design aspects they felt impacted on the effectiveness of the signs as part of their response. Despite similar results in terms of the signs being identified as a warning at both locations, further analysis indicated striking differences regarding the number of comments identifying problems with the design of the sign at Palm Cove as compared to Waikiki. There were 41 comments by Palm Cove respondents and only 3 by Waikiki respondents. The Palm Cove comments include 7 relating to the absence of an alert word or colour (e.g. “Needs a DANGER”; “Red means danger”; “Red is stop, don’t do this”), 21 (20 by tourists) describing the text or sign as confusing (e.g. “Marine stingers is meaningless”, “I don’t know what the words mean”, “I’m puzzled by the sign”, “Don’t understand it”), and 4 comments by 2 locals and 2 national tourists describing a lack of risk communication (e.g. “Signs do not explain what happens”, “They don’t convey the message that stingers are deadly”) or how to avoid it (e.g.

“It does not say to wear a stinger suit”). In comparison, comments made by Waikiki respondents include 1 relating to each of the following: absence of an alter word (“they need to put CAUTION or DANGER on the sign”); unknown risk (“jellyfish insects, no idea what happens”); and sign visibility (“I can’t always read them”).

Willingness to enter the water

Table 2 also shows the dominant theme identified, water safety, that emerged from responses to the question “Is there anywhere at this beach where you would swim or enter the water?” Two sub-themes emerged from the water safety theme: perceptions of safety in regards to entering the water and jellyfish visibility.

As to the first sub-theme, perceptions of safety in regards to entering the water, data indicated that 76% of the Palm Cove respondents incorrectly identified the stinger net as a safe place to enter the water (e.g. “The nets are safe-you can swim in them”, “It is safe in the nets and between flags”). Those respondents that correctly described the nets as unsafe (13 locals and 17 tourists) knew that it was because of the Irukandji hazard (e.g. “it is safer but Irukandji small ones could get in”; “Irukandji could get washed over because of choppy water”). As a point of interest, 10 respondents (7 international tourists, 1 national tourist and 2 locals) spoke of the source of their knowledge about the danger of swimming outside of the stinger net as coming from other people (e.g. “local friends”, “Lifeguards”, “my daughter”, “the TV”) and not from the warning signs (e.g. “I recognised the picture but no idea what the words meant”) casting doubt on the sign’s effectiveness.

Fewer of the Waikiki respondents, 48% (83% locals, 54% national tourists and 42% international tourists), indicated it was safe to swim or enter the water and 52% (17% locals, 46% national tourists and 58% international tourists) indicated that it was not safe. In the absence of nets at Waikiki beach, 24 comments emerged around safety and depth of the water (e.g. “I might put my feet in”, “I would go up to my knees”, “I would go shallow and paddle up to my waist”) suggesting there may be some misconception that dangerous jellyfish are not present in shallow water.

As a group, the Palm Cove locals who were regular beach visitors, provided the highest number of comments describing the nets as unsafe against the Irukandji hazard. The Chi-square tests on variables (sign viewed, perception of safety and number of beach visits) indicate that for the local group, there was a significant association between visits and seeing the signs (χ^2

(2, N= 109) =10.54, $p = .005$. Those visiting for the first time reported a significantly lower proportion of seeing the signs. The locals also reported an association between having seen the signs and their perception of safety (χ^2 (1, N= 109) =6.5, $p = .011$). The association between seeing the signs and perception that it was unsafe to enter the water was significantly higher for locals. No significance was found in the other 2 groups with regards to this. To identify if there was an association between visits to the beach and perceptions of safety, first time visitors were compared to those who had been to the beach more than once. Domestic tourists who were visiting for the first time reported significantly lower levels of perceptions of safety in terms of entering the water. Domestic tourists who were regular visitors reported significantly higher levels of it being unsafe (χ^2 (1, N= 108) =11.47, $p = .002$). These two findings were also found for the international tourists (χ^2 (1, N= 109) =11.70, $p = .004$). No significance was found for the local group. Waikiki data was not tested for these variables due to the absence of stinger nets and the low number of respondents who stated they saw the sign.

An additional sub-theme, jellyfish visibility, emerged around perceptions of safety in entering the water. Some comments suggested there may be a misconception that jellyfish are visible in the water. There were only a few comments but this idea was found to emerge at both locations. Evidence of an expectation of jellyfish visibility and an ability to act to avert danger was captured in some of the comments by tourists (e.g. “if I see people getting stung I’ll probably get out of the water” (Palm Cove); “I would go shallow cuz you can see them” (Waikiki). One local respondent interviewed at Palm Cove beach, had with her a young child who was waist deep in the water outside of the net and similarly commented “I’ll keep a lookout and get out if I see any”.

Conclusion and recommendations

This study has shown that the effectiveness in communicating jellyfish hazards at high volume tourist beaches is improved if the signs are designed in accordance with research based standards for effective warning signs and they are noticeable. In this study, 214 beachgoers (109 at Palm Cove beach and 105 at Waikiki beach) were asked whether they had noticed the sign when they approached the beach that day, then to interpret the sign, and finally whether and where they would enter the water. Overall, 85% of respondents were tourists with international tourists representing the largest group and locals the smallest group.

In terms of noticeability, a significantly higher number of beachgoers at Palm Cove (80%) observed the jellyfish warning than at Waikiki beach (18%). The large disparity between

these results might be explained by the presence of environmental factors at both beaches. Despite the signs being well positioned at the shoreline to increase noticeability, they were in the presence of rich environmental stimuli which increases the need for greater attention to the placement of signs to ensure they remain conspicuous for the period they are displayed.^{39,10} At Palm Cove beach, this was achieved by positioning the warning signs next to the stinger net and flags, both attention grabbing stimuli, and away from other competing signs or beach equipment. The warning signs, despite the absence of an alert panel, stood out and were conspicuous, drawing beachgoers attention even at the busiest parts of the day.

At Waikiki beach the signs were far less noticeable from around midday when the crowd was most dense. People located themselves closer to the warning signs to avoid being cramped, many with red and yellow beach umbrellas that stood at a similar height as the signs. Despite the sign containing an alert panel to increase noticeability, this was not sufficient to influence respondents to switch their attention away from competing stimuli to the warning signs. Interestingly both results are inconsistent with results of other beach signage studies in the US and Australia where around half of respondents interviewed noticed the warning signs.^{21, 16} In research studies that use an after-the-fact self-reporting method, the accuracy of results that aim to measure the noticeability of signs have been brought into question based on participant factors such as poor memory.¹⁰

In terms of interpreting the signs, this study found the US sign was far more effective in communicating the hazard than the Australian sign. Despite a high rate of respondents describing the signs at both locations as referring to jellyfish, the Australian sign did not effectively communicate the hazard to a high rate of beachgoers, whereas the US sign did.

The high rate of sign observation by Palm Cove respondents, did not translate into knowledge or understanding of the Irukandji health hazard inside the stinger nets at Palm Cove, where 80% of tourists described it as a safe place to enter the water. International tourists were found to be least able to associate the sign as a warning against the Irukandji and the type of danger it presents, despite being the highest group to associate the sign with swimming safety. These results are consistent with other studies that have found a high rate of tourists assume the nets provide safe places to swim.²⁷ As a group, local respondents were most able to describe the sign as a warning and that the nets were not safe against the Irukandji. This is consistent with the higher likelihood for locals being exposed to marine stinger signage and repeated

informative media campaigns. Of concern, despite such exposure, 54% of locals interviewed indicated that it was safe inside the stinger net.

This perception of safety inside stinger nets is most likely influenced by a range of factors including the presence of lifeguards encouraging beachgoers to only swim within the netted and flagged area.⁴⁰ There is evidence that the “swim between the flags” message has become a message that beach flags at patrolled beaches indicate a safe place for people to swim.⁴⁰ Marine stinger warning signs positioned near stinger nets may be sending mixed safety messages to beachgoers as the signs do not warn of the hazard inside the nets presented by the Irukandji jellyfish. .

In the Waikiki context, all but one respondent correctly interpreted the sign, indicating that the design of the sign makes it a highly effective warning, provided it is noticed or seen. This study found, that as a group, international tourists were most able to describe the sign as a warning against dangerous jellyfish and that it was unsafe to enter the water. Almost 6 times more comments (83) by Waikiki respondents correctly described the jellyfish as dangerous or harmful to people as compared to comments (14) by Palm Cove respondents. Again, while it was encouraging that the sign effectively communicates the hazard, of concern was the rate of beachgoers interviewed (82%) who did not recall noticing the sign.

Design Modifications

Limitations about the design of the signs, particularly Australia’s sign, were also identified in this study. Unlike the US sign, the “marine stinger” sign does not meet all of the research-based design guidelines for effective warnings.

Communication of the hazard, at the site of the hazard (inside and outside of stinger nets) might be more effective if two signs were created: a general sign for outside the nets and an Irukandji specific sign for inside the nets. This suggestion is based on comments by some tourists about the sign’s text (e.g. “marine stingers is meaningless to me”). When measured against the design guidelines for effective warnings, the sign should include text and symbols that inform readers that the Irukandji is a jellyfish, the size and dangerousness of the Irukandji, and specifically, that the hazard may be present inside the stinger nets. Additional text stating the consequences of exposure (e.g. “a sting can cause serious injury or death”) and how to avoid it (e.g. “wear protective stinger suits in the water”) or some variation of this is also recommended to improve risk communication.

Similar modifications would also be appropriate for a general marine stinger warning sign but the message would be more accurate if the symbol was modified. A pictogram that indicates scale such as symbols of both the larger box jellyfish and the tiny Irukandji next to a person symbol in water might lessen critical confusion by locating the “stinger” hazard in the water and lessen beachgoers expectations that “little ones” can be seen and that there is only one “big” life threatening jellyfish at Australia’s beaches.

Any design modifications of the sign would also require interpretation testing as generalising the results of this study to other Irukandji prone areas could be problematic. Comprehension and perception of stinging jellyfish and sting risk can vary between nationalities^{1,41} and as this study indicates, most beachgoers in summer at these locations are tourists.

From the theoretical perspective raised by some researchers about the risk communication process, human factors such as the individual’s own background and previous life experiences can contribute to assessments of danger and response behaviours to risk.⁴² The attention given by beachgoers to warning messages may also take second place to their own beliefs that the beach is relatively safe, or that the potential hazard would not happen to them.¹⁶ A lack of knowledge or experience can cause people to become less concerned about safety issues and hazard-related signage.⁴³

However, to determine what motivates the behaviour of beachgoers in the presence of warning signs is beyond the scope of this study and would require further research. This study highlights the importance of regular testing of beachgoers interpretation of warning signs in the field. Simple modifications to the design of Australia’s marine stinger sign in line with research based warning design guidelines might improve its effectiveness as a warning and modifying the placement for visibility of the US jellyfish sign might improve its effectiveness.

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