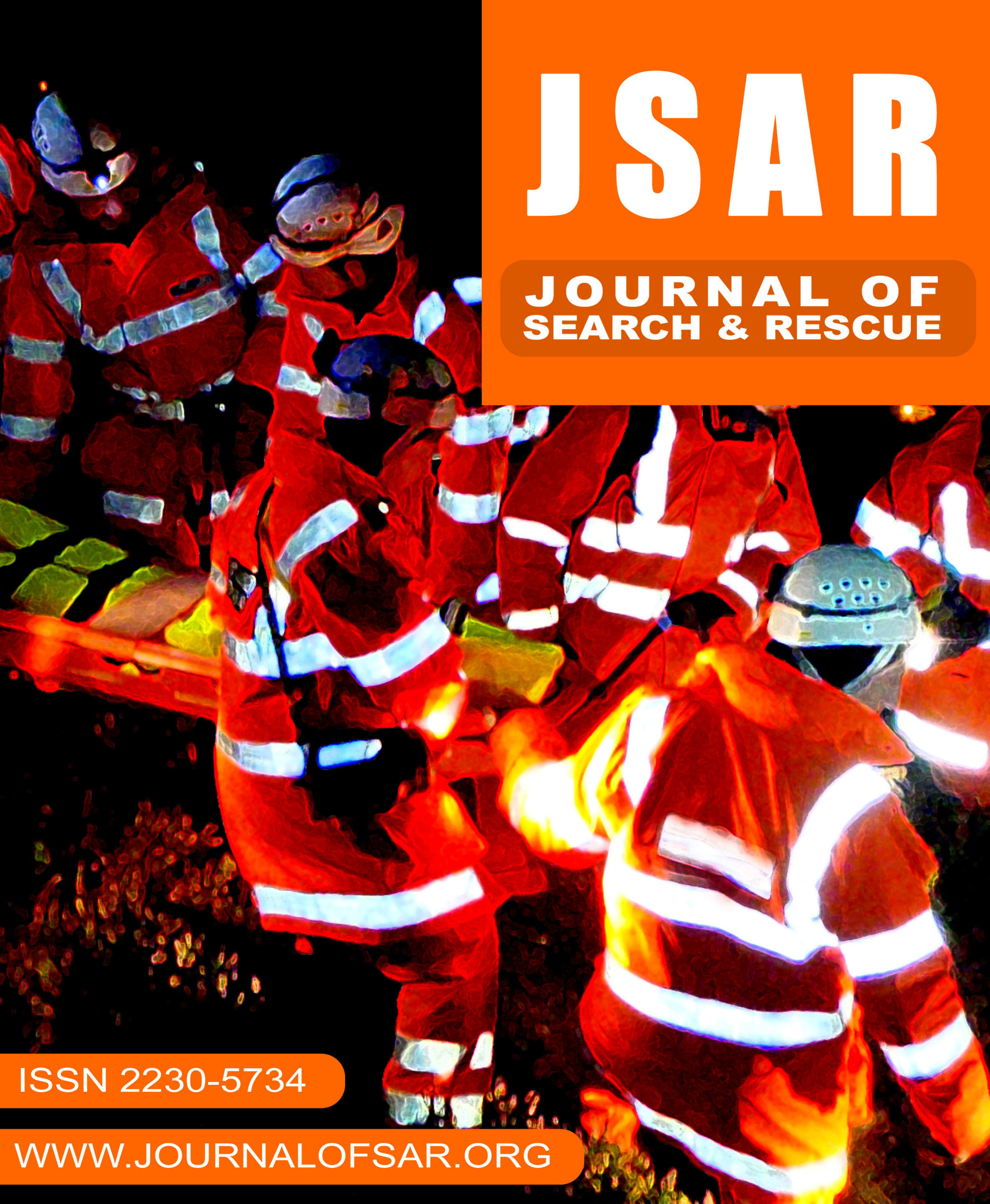

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"A free peer-reviewed electronic journal utilising the internet as a medium for the collation and distribution of original, scholarly, yet practitioner focused material on search and rescue."

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Foreword

26 January 2013

On behalf of the Editorial Board, it is my pleasure to welcome you to the inaugural edition of the *Journal of Search and Rescue* (JSAR). JSAR stands to provide a free peer-reviewed electronic journal utilising the internet as a medium for the collation and distribution of scholarly, yet practitioner focused material on search and rescue.

The work of the honorary editorial board has been immense over the past eighteen months and I would like to thank my fellow board members as well as those who have contributed to the peer review process.

I would like to provide special acknowledgement to Daniel Graham who developed our website and to our Editorial Coordinators, Duncan Henry and Elizabeth Barney. These three people have been critical to establishing JSAR and the publishing of our first edition.

JSAR benefits when search and rescue practitioners actively and academically contribute to the *body of knowledge* and we are always on the search for submissions. Where aspiring authors need support in writing an article, we also offer mentoring from seasoned practitioners who also are academics.

I invite all higher education institutions involved in public safety to encourage students and faculty to join our Facebook and LinkedIn groups to remain connected and involved in the journal.

Finally, this issue has an exciting broad range of research topics that any SAR practitioner will not only find fascinating, but also challenge their assumptions and the myths in our disciplines, so that we evolve international best practice – to save life. I hope you will enjoy our first edition, the first of many to come.

Steve Glassey
Editor-in-Chief
Journal of Search & Rescue

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Cover Image:

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Notice:

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Auditory and Light Based Two-Way Effective Sweep Width for Responsive Search Subjects in New Zealand Mountainous Terrain

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Abstract

Search theory is completely dependent upon an accurate assessment of how well a search area was covered by a team or the Probability of Detection (POD). Determining the POD for auditory whistle blasts and a response to sighting lights at night (sound-light line technique) involves a two-way detection problem.

Two experiments were carried out at Nelson Lakes along the Porika Road track in New Zealand. The first experiment was conducted during the day with six subjects and fourteen two-person teams conducting a sound line tactic. The detection index for a search team hearing a shout was 332 meters. The detection index for a subject hearing a whistle was 401 meters. Searchers were able to detect 99% of high-visibility clues (orange gloves) and 52% of low-visibility clues (gray gloves) on the track. The night experiment was conducted at the same location, but with different search subjects placed in different locations. Search teams used a sound-light line tactic in two-person teams. The detection index for a search team hearing a shout was 306 meters. The detection index for a subject hearing a whistle was 395 meters and seeing a light 277 meters. The detection index for a subject detecting either signal was 460 meters.

This is the first report in the land search literature of both elements (searcher and subject) of a two-way detection problem.

Keywords: Detection index, Sweep Width, two-way detection, Probability of Detection, POD, whistle, shout, sound-light line.

Introduction

Koopman (1946, 1980) established search theory and practice with his pioneering work during WWII. Prior to his work there was no published scientific literature on search theory. An essential part of Koopman's work was developing the concept of Effective Sweep Width (ESW)—a single numeric value of detectability for a given sensor to detect a specific search object in a unique environment. The ESW can then be used to calculate the Probability of Detection (POD), a measure of a search team's thoroughness. While determining the POD is critical to search theory it is not the ultimate goal. Instead POD is used to determine the Probability of Success (POS) in conjunction with the Probability of Area (POA). In turn POS is used to determine the Probability of Success Rate (PSR) which can be used to make decisions on the optimal allocation of resources in the field (Charnes and Cooper, 1958). For additional information on the full development of search theory and ESW see Frost (1999a, 1999b, 1999c, & 1999d).

Lateral Range

The method for estimating the ESW uses the concept of a "lateral range curve" introduced by Koopman (1946). Lateral range refers to the perpendicular distance an object is to the left or right of the searcher's track where the track passes the object. Therefore, it represents the distance from the searcher to the object at the Closest Point of Approach (CPA). A lateral range curve is a plot of the probability of detecting the object on a single pass as a function of the object's lateral range (distance) from the searcher's track. **Figure 1** shows a hypothetical relationship between POD on a single pass and an arbitrary scale of distances to the left (negative) and right (positive) of the searcher's track. Negative values are distances to the left of the searcher's track while positive values are distances to the right of the searcher's track. The shape of the lateral range curve is determined through actual field experiments. Twardy (2012) provides a recent discussion on the various shapes a lateral range may take.

Auditory search is also highly dependent on distance. However, it differs from visual search in that it is possible to know the distinct distance for each and every auditory attempt. It is also different in that each auditory signal is discrete. In fact a searcher making a continuous sound would be unable to listen to a response. It is also possible to determine if each auditory attempt of the team (whistle blast) was detected or not detected. This unique feature allows analysis using both the CPA and to determine an alternate detection index from each discrete detection opportunity.

The lateral range method also functionally integrates all of the effects various factors have on the detection process during the experiment. Even in a fairly constant environment many factors may affect detection. Wind or rain may affect hearing at a particular point; one searcher may have better hearing than another; or the object may require several glimpses to register on the consciousness of the searcher, especially if it has a low contrast with its surroundings.

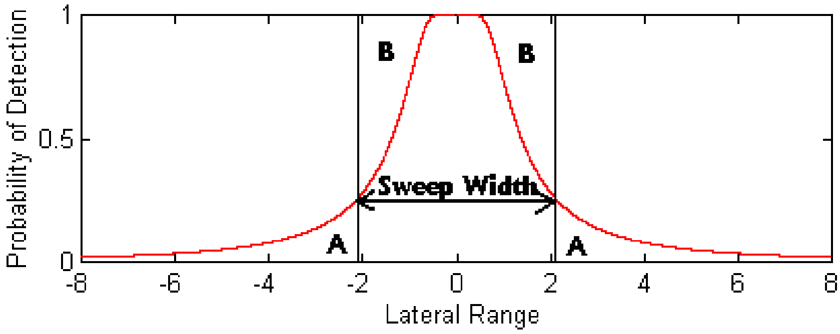

Figure 1 A Lateral Range Curve. The number of missed detections (B) inside the effective sweep width equals the detections (A) that occur outside the sweep width. This is often called the cross-over point. Figure from Frost 1999b.

Detection Index (Effective Sweep Width)

The ESW is one of the central concepts of search theory and its application to SAR. Additional information about ESW may be found in Koopman (1980), Stone (1989), and Frost (1999b).

The ESW may be thought of as the area where the number of objects *missed inside* the swath are equal to the number of objects *detected outside* the swath as shown in **Figure 1**. In more mathematical terms the ESW is also numerically equal to the area under the lateral range curve. Robe & Frost, (2002) previously showed for land search that the cross-over technique based upon finding the point where the number of cumulative detections equals the number of cumulative misses is equalvalent to calculating the area under the curve, and may in fact be superior. The technique has also been used by Koester et al (2004) and Chiacchia & Houlahan (2010) for visual search. An ESW value has not been determined for auditory search.

Probability of Detection (POD)

Successful search planning, whether in an urban, wilderness, or marine environment requires an objective standard for providing an estimate of the Probability of Detection (POD). In each of these settings the variables that describe the searcher, the search object, and the search environment will differ not only in kind but also in their influence on the estimate of the POD. What is constant, however, is that POD estimates should be based on objective measures and observations. Previous research by Koester et al (2004) found experienced searchers were unable to make accurate assessments of POD based upon subjective assessments by either the search planner or the searchers. POD depends upon coverage, which depends on three things:

- The "detection index" or ESW for the combination of search object, search environment, and sensor (e.g., auditory search from the ground) present in a given search situation,
- The amount of effort expended in searching the area, and
- The size of the area where the effort was expended.

The size of the search area requires special comment when the field technique of a sound light line is being used. The tactic places a team of searchers following a linear feature. Since each member of the team follows the same course, increasing the number of team members does not increase the total track line distance. Instead, any advantages of additional team members would be derived from factors such different abilities to hear, differences in types of whistles, differences in listening orientation, differences in attention, and other subtle factors. The size of the search area, since linear in nature, should be defined by how far off the route a POD is desired. This also simplifies the inputs and computation required to determine the POD value.

Previous Related Experiments

Koester et al (2004) reported on five visual experiments conducted in different environments for high, medium and low-visibility search object approximating prone search subjects. Chiacchia & Houlahan (2010) followed up with two additional visual experiments with similar results and using the same methodology.

No previous study used the combination of un-alerted searchers and subjects for auditory search. In addition, no previous studies have reported the POD values for clues placed directly on the track which is a common search tactic. Only two previous SAR experiments involving sound have been conducted. Martin Colwell (1992) conducted field trails to determine both visual and sound Probability of Detection (POD) in British Columbia. More specifically the experiment was conducted in a Pacific West Coast coniferous forest (Marine Temperate ecoregion division). The experimental methodology involved placing dummies in a standing position. The dummies were outfitted with inexpensive, portable, battery powered

AM radios. The radios were tuned to a local “talk” radio stations the volume adjusted to best match a person talking loudly or shouting. Manson (2009) reports that some of the researchers who had placed the subjects were also involved in the detection experiment. Colwell’s results are reported as the searcher’s POD based upon the spacing. While this allows creation of a lateral range curve and therefore finding the area under the curve (one method to determine an effective sweep width), this value was not calculated at the time. The actual value would be expected to be underestimated since the experiment required the searcher to also make a visual detection of the search subject in order to identify the dummies code number. Manson (2009) conducted research looking at sound in the same environment as Colwell. He looked at the relationship of loudness and range using different whistles. His experiments showed that loudness does not always directly indicate a whistles range, since pitch is also an important factor. The experiment reports an attention-getting range for each source, although this was a subjective value determined by the testers.

To date no experiment has attempted to determine the detection index or effective sweep width value for auditory search that is required to determine an objective POD. In addition, no experiment has ever been conducted to look at the use of light in getting a subject to respond. Finally, no previous experiments have looked at the real-life issue of the two-way nature (lost subject detects searcher shouts and then searchers hear subjects response) of the signal detection in the land environment.

Methodology

The methodology used was similar to visual land based experiments previously described by Koester et al (2004). That methodology was further refined and described by Koester et al (2006). An important tool used to setting up experiments is the Integrated Detection Experiment Assistant (IDEA) which is built using MS Excel. Required inputs include the projected number of search participants, the number of different types of search objects, and the Average Maximum Detection Range (AMDR). The calculator would then determine the total number of targets required, expected length of course, expected time to complete the course, and locations to place search objects (subjects). If the number of targets or course time fell outside the experimental parameters the parameter was flagged by a change in color. In addition to setting up the experiment, IDEA displays the results after inputting raw data. The experimental design calculator was a useful tool for the experiment team but is not a finished product in regards to sound-light experiments. Key differences in the experimental methodology of Koester et al (2004) and the auditory experiments are described.

Determining AMDR

During the site visit an Average Maximum Detection Range (AMDR) was obtained. The AMDR protocol was modified from the visual protocol described by Koester et al (2004) in the following ways. The AMDR was conducted by taking four measurements instead of taking sixteen measurements as specified in Koester et al (2004). The reduction was due to measuring only the extinction point (i.e., point unable to hear the whistle or shout) and reducing the number of legs from eight to four. Since the distances were large a GPS (Garmin 60CSx) was used to obtain coordinates and then measure the actual distances using Google Earth software. Since it was unknown what the difference between voice and whistle might be, both were provided. A total of three people were involved in the AMDR collection. One person stood at a fixed location. Once every two minutes a whistle was blown. Also every two minutes a shout was made. Combined, this meant either a whistle or shout would occur at the same time every minute. This allowed the "searchers" walking away from the sound source to know if the signal heard was valid. The goal is to achieve the maximum distance possible and still hear a valid signal.

Marking the track

In the sound-light experiment a two-way detection is required. The searcher must signal the subject, the subject must detect the signal and respond, and finally the searcher must detect the signal the subject sent. Therefore, it was important to control the exact location that each whistle blast occurred. This was accomplished by precisely marking the track. A one-meter measuring wheel was used to measure the course. Every 100 meters the location was marked (see **Figure two**) and the coordinate entered into a Garmin 60CSx GPS receiver. The location was indicated with an orange traffic cone marked with the appropriate distance and reflective white or red reflective tape. The cone was held in place by a fiberglass rod driven into the ground with a mallet and further enhanced with surveyor's flagging tape.

Figure 2. Cone used to mark every 100 meters along the track.

Prior to the experiment the several forms were created in order to collect data, manage experiment participants, brief participants, and ensure searcher safety.

Visual Glove experiment

The day time experiment also had clues placed on the track. The clues consisted of either high visibility clues or low-visibility clues. The high-visibility clues were white workers gloves painted with day-glo orange dazzle (paint), and the low-visibility clues were the same gloves painted gray. One low-visibility glove was left white, since it was placed on some snow. Locations for placing the gloves on the track were determined by IDEA. Searchers were informed to record any gloves they located.

Participant Recruitment

Participants were recruited mostly from Tasman Search and Rescue, the New Zealand Police, and some additional participants recruited from the Canterbury district. All searchers belonged to a search team or played an active role in search and rescue.

Basic Protocol

The sound-light experiment used search and rescue (SAR) personnel for both search subjects and searchers. The searchers used whistle blasts (day) or a combination of whistle blasts and light (night) to send a signal to the search subjects. Teams used technique taught in the SARINZ Search Methods course and corresponding student reference (Wells et al, 2012). If the search subject detected a signal (either a whistle blast or shining light) they responded by shouting “Hey, it’s Bravo.” Each subject was assigned a unique phonetic alphabet word to shout. The order of the words were randomized

All participants signed in on the participant sign-in sheet and were assigned to a team. Teams were staggered at a 15 minute interval. Each searcher provided basic information on the Searcher Profile form. The form is broken into three sections. Section A collects demographic information on the searcher. Section B collects physical characteristics such as hearing, vision, and height. In addition it collects information on the physical characteristics of the searcher’s whistle and flashlight. Section C is filled in during debriefing and includes collected weather information, estimated PODs, and self-reporting of morale and fatigue.

The search subjects and searchers received separate briefings. The searchers were not aware of how many subjects were placed into the field. Each search team carried equipment needed to safely function in the environment (typical SAR pack) and a copy of the searcher information sheet, task assignment form, detection log, guide to determining Beaufort scale, clip board, pencil/pen plus a backup writing tool, and may have been issued a radio. The team’s departure was tracked on the Team Tracking Log. Actual position reporting, once the team was dispatched was greatly facilitated by the numbered cones. Teams, instead of reporting coordinates, only need to report the closest cone number.

Upon completing the experiment (returning from the field), each team was debriefed and the detection log examined to ensure it was filled in correctly or if any questions existed. The Detection Log form has a tabular representation of the search track. A row exists for each 100 meter cone. Each detection made by the searcher is recorded on the log along with its description, time, wind condition at the time (using the Beaufort scale), and clock bearing relative to 12 o’clock being straight ahead on the track. The time was recorded for every 100 meters (cone location) where the team blew a whistle.

Current weather and changes in the weather conditions are recorded at the command post using a Kestrel 4000. The weather characteristics recorded were precipitation, cloud cover, temperature, visibility, barometric pressure, humidity, and wind speed.

Data Scoring

Data was scored in the same manner as described by Koester et al. (2004). Some differences between a visual experiment and auditory experiment are described. Subject's location were recorded by the subjects using a Garmin GPSMAP 60CSx GPS receiver and recorded on their detection logs. The GPS was setup to New Zealand Grid and the WGS84 map datum. The New Zealand Grid was used so subjects could locate themselves on the gridded map. The grid coordinate was then transformed to a decimal degree format using Franson CoordTrans version 2.3. The decimal degree subject coordinate was plotted using Google Earth. The subject's location was then compared against the previously plotted cone coordinates and the subject placement sheet which was used to place the subject's. If the location, side of the track, and distance matched it was considered a valid subject location. All subjects' had valid locations. It was also noted (using Google Earth elevation features) if the subject was uphill, downhill, or at the same level as the cone location of closest point of approach. All scoring was done by one individual to ensure consistent results. Each search object would be scored as either being detected or missed. Virtual search objects (described in Koester et al. 2004) were not placed onto the Detection Log scoring template and were all scored as misses.

Data Scoring Closest Point of Approach Method

It was possible to score the detection and non-detections using several different techniques. Detecting the search subject involved the team sending out a whistle blast at each cone and then listening for a response. A chart was prepared that showed each subjects point of closest approach or lateral range between the cone and the search subject. Each time would then be scored a "1" if the search team detected the subject's shouts and a "0" if it did not. It was possible to score the sheets rather quickly for this technique.

Data Scoring Each Cone Method

Unlike visual experiment where detections and non-detections can occur anywhere along the track (thus requiring the CPA method) sound experiments send out a discrete signal from a fixed and known location to a subject at a fixed location. Since the coordinates of each cone were recorded along with the subject's it was possible using a GIS system to measure the distance between each cone (site of the searcher's whistle blast) and the subject. The measurement ruler is precise to 0.1 meters and measurements were recorded to the closest meter (see **Figure 3**).

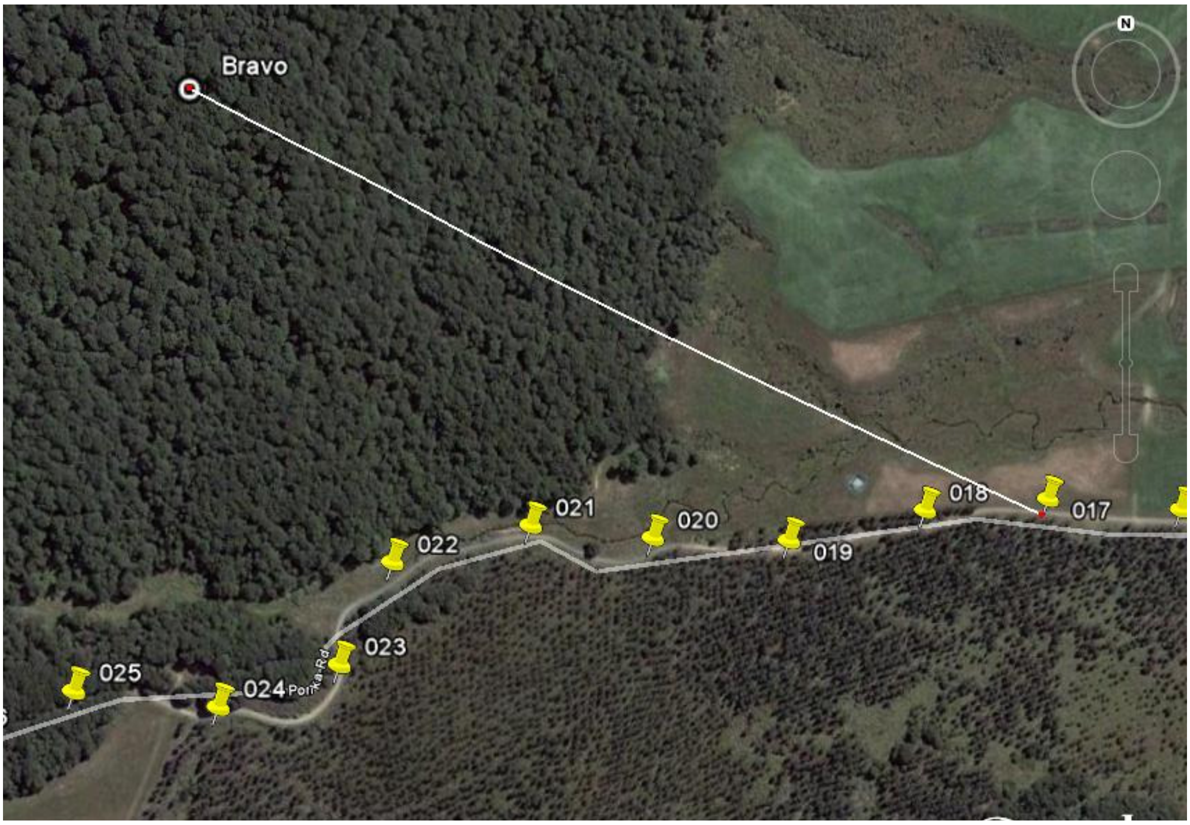

Figure 3 Method used to measure the distance from subject to each cone location

Each cone was then assigned to one particular subject (using midpoint between two subjects). The lateral range from that cone to the assigned subject was made. Then each team's detection or non-detection was scored for each cone. During the day experiment this results in 1327 detection opportunities versus the 115 using the CPA method. The lateral ranges were then placed into bins and the average of the distances within each bin was used to determine the lateral range for each bin.

Data entry was then made into the MS Excel based IDEA Data input Search Object 1 sheet. The clue number, lateral range (or off-track distance), and clue type were entered. Then for each searcher (using their coded searcher number) the "0" and "1" were transcribed from the scoring form into the spreadsheet.

Data Analysis

Using the information provided on the spreadsheet, another worksheet (Data Summary Object #1) automatically calculated the crossing over point of the cumulative detections and cumulative misses after the automatic sort button is clicked. The purpose of the clicking on the sort button is to sort the lateral ranges from smallest to greatest. It is then possible to calculate the detection index.

The first step in scoring was starting with the team detections. If the team heard the subject, then by default the subject had heard the team. The next phase was to determine if the subject had heard the team, even when the team did not hear the response. The trackline distance where most teams had heard the subject was recorded. Then in a separate worksheet the exact time each team reached that particular cone (trackline location) was recorded. Finally, the team's cone time was cross-referenced to the subject's detection log. If the two times matched then the subject scored a detection for that particular team. One team did not record their cone times so it was not possible to score that team.

Results

Description of Venue – Nelson Lakes St. Arnaud

Nelson Lakes National Park (established in 1956) is situated in the north of New Zealand's South Island. This park protects 102,000 hectares of the northern most Southern Alps. The park contains beech forest, craggy mountains, streams and lakes both big and small.

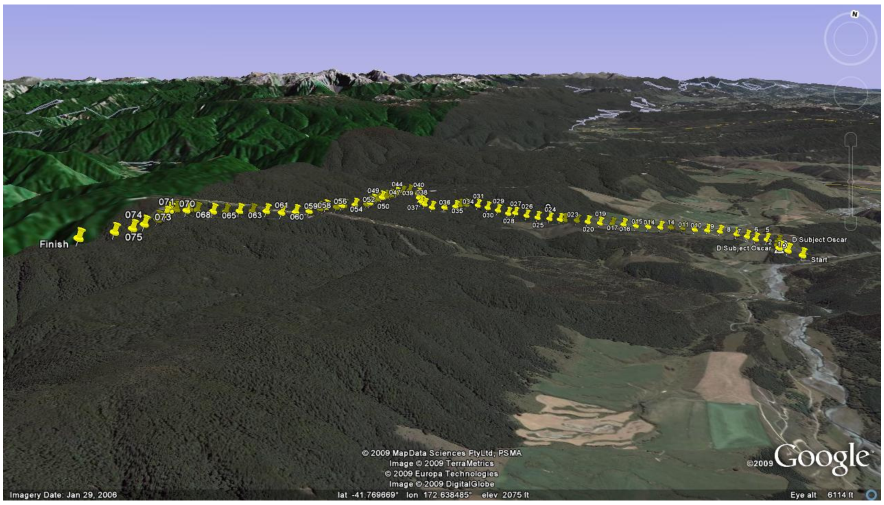

Figure 4 Google Earth view of search track with cone locations plotted

Two separate experiments were carried out at Nelson Lakes on July 18 and into the early hours of July 19, 2009. The first experiment occurred during daylight and looked at the sound line tactic and clues placed on the track. The second experiment occurred after dark. New subjects were placed in different locations. The night time experiment involved both sound and light line tactics. For each experiment the detection index can be determined by using the Closest Point of Approach (CPA) technique or from each cone's position.

Course Characteristics

Table 1 provides the general characteristics of experiment conducted at Nelson Lakes.

	Day	Night
Location	Porkia Road, Nelson Lakes	
Ecoregion	Mountainous Subtropical M230	
Season	Winter	
Length	7.5 km	
Elevation Change	467 – 983 meters	
Layout	Road	
Temperature	10-12 C	1-5 C
Wind Speed	0-10 kph	2-45 kph
Visibility	Unlimited	Unlimited – 200 meters
Cloud Cover	Partly Sunny	Clear – Foggy
Precipitation	None	Rain Moderate
Pressure	943 mb falling	943 mb
Time	11:28 – 17:57	20:36 – 01:34

Table 1 Course general characteristics

Day time Experiment – Team Detection Experiment Results

In several cases it was observed that the subject in fact detected almost all of the teams. However, almost none of the teams detected the subject. This would result in a larger detection index for the subject detecting the teams. This is in fact the actual result. The team's detection index (CPA method) was 332 meters and the subject's detection index was 401 meters.

Day time Experiment – Clue Detection

The clue detection experiment only took place during the day. The original intent was to conduct the clue detection experiment at night. Therefore, the clues were placed (using IDEA to determine the locations) the previous day. A total of 12 orange gloves were placed, 11 gray gloves, and 1 white glove (placed on snow). Out of the 15 teams that turned in a detection log only 12 completed the log in such a way it was possible to score the clues.

The last team (team 14) consisted of one of the officers who had help setup the course. He had specific knowledge about the white glove. Therefore, that particular glove from team 14 was thrown out. The range of POD% for the orange glove was 92% - 100%. The range of POD% for the low-visibility gloves was 25% - 83%. The results are summarized in table 4.

Night time Experiment – Subject Detection Light Experiment Results

In addition to the whistle blast, teams were using sound-light line tactics. Therefore, the subject also had the potential to detect the teams light. Subject's were instructed to only respond to whistle blast, but also to record when they detected light. The technique for scoring was the same method to use to determine which whistle blast matched a particular team. The detection index for subject's detecting light was 277 meters.

Predicted versus actual detections.

As part of the debriefing process, each searcher was asked to give what percentage of the potential targets did they detect? This is similar to a typical debriefing question asked on many searchers in order to obtain a "POD" value. Since the number of search objects were fixed and known, it is possible to determine how accurate the searchers were with their predicted POD versus the actual POD.

Parameter	Average Predicted	Range Predicted	Actual % Detected	Offset
Sound (Day)	29%	0-90%	33%	± 18%
Sound (Night)	38%	5-75%	59%	± 23%
Orange Glove	84%	60-100%	99%	± 21%
Gray Glove	68%	10-100%	53%	± 37%

Table 2 Searcher ability to predict Probability of Detection (POD)

Overall Summary Experiment Results

The table below provides an overall summary of both day and night experiments.

Detection Type	Method	Day Experiment ESW	Night Experiment ESW
Searchers detecting subject shouts	CPA	332 m	306 m
Searchers detecting subject shouts	Cone	276 m	262 m
Subject hearing searchers' whistle	CPA	401 m	395 m
Subject seeing searchers' light	CPA	NA	277 m
Subject detecting searchers (light or sound)	CPA	401 m	460 m

Table 3 Summary of ESW results

The Probability of Detection (POD) for a glove on the actual track during daylight.

	Number	Detection Opportunities	Average POD%	Average POD%
Orange Glove	12	144	99%	99%
Gray Glove	11	132	57%	52%
White Glove	1	11	0%	

Table 4 Summary of detection results for clue on track

Discussion

The experimental methodology was built upon the solid foundation of previous visual experiments to determine land-based detection indexes. The design and methodology of the visual experiments were in turn based upon maritime experiments conducted by the US Coast Guard Research and Development center. Key concepts such as detection opportunities, scoring each detection and non-detection, closest point of approach, looking at and for correction factors, generating lateral range curves, and using the cross-over technique to generate the actual detection index value have all been previously validated by Koester et al (2004).

The fundamental issue with sound and light detection is the two-way nature of the detection. It requires two cooperating elements that wish to find each other. The searcher desires to detect the search subject and the search subject wishes to be found. The search team sends out an initial signal (sound and/or light) and the subject must first detect the signal; recognize it for what it represents, and then respond in some fashion. Based upon conversations with SARINZ instructors it was determined the most common signal generated by search teams is a whistle blast. Then depending upon the subject type and scenario teams will sometimes augment the whistle blast by shouting the subject's name. It was then stated that approximately 90% of the time the response is a shout from the subject. Therefore, from an experimental point of view the ideal "search object" would be one that could recognize a whistle blast and then respond with a human voice. It was felt a human voice would be important since human sensory and processing systems are ideally suited to recognize a human voice across many different frequencies and hidden in background noise (Lewis et al, 2009). It was also felt the reply voice should be a short discrete signal and not a constant noise to aid in the detection of the voice. Therefore, it was decided that by using actual humans as the search subjects a detection index which actually reflects reality most closely would be obtained. More importantly, in the real world subjects don't know when they will hear a shout. The experiment methodology ensured that search subjects were un-alerted. In other words, they did not know when a team would whistle. In return, search teams were also un-alerted, since they had no idea when they would hear a reply. Future experiments should continue to use actual subjects.

While this first auditory two-way land detection experiment resulted in several key findings, the results should be viewed as preliminary and not definitive. The experiment clearly showed it was possible to obtain a detection index for sound and/or light line tactics. Furthermore, the fact that the closest point of approach method (with 115 detection opportunities) and the cone method (with 1327 detection opportunities) provided similar results indicates experiments with approximately 100 detection opportunities can be conducted. This is further bolstered by the fact that the day and night experiments resulted in a team detection index of 332 and 306 meters respectively, a difference of only 8%. The difference for the subjects hearing the whistle was only 1%.

This experiment was the first reported experiment of detection of light in a realistic search environment. Since the experiments took place in a forested area in mountainous terrain, it is expected that distances would be small. In fact, the detection index for a subject detecting the light was 277 meters. It is interesting to note that the detection index for light appeared to be independent of the detection index for sound. In some cases the subject detected the light without detecting the sound. In other cases a subject detected the sound without detecting the light. This means the overall probability of making some type of detection increases. Therefore, the detection index (ESW) for a subject detecting a team increased to 460 meters (when both sound and light were considered. It is important to realize that the detection index is not the maximum range of a possible detection but instead is either the area under the lateral range curve or the distance where the number of missed detections equals the number of detections. Depending upon conditions, it is expected that the detection index for light would be large.

While no previous studies generated a detection index for un-alerted searchers, the maximum ranges provided by other experiments do provide some insight. A previous test of several different whistle types conducted in New Zealand (B Were, personal communication, 2006) showed for the loudest whistle the maximum range was between 300 to 500 meters depending upon the conditions, compared to our results of a detection index of 400 meters for a subject detecting a whistle. After taking into account differences between alerted and un-alerted searchers, different whistle types, and the left/right nature of a detection index, the results are somewhat comparable. The first classic sound study was conducted in Canada (Coldwell, 1989). This study was conducted under more search-like conditions. The study results were reported as a lateral range curve. Using the cross-over technique found in IDEA it is possible to convert a lateral range curve into a detection index. This gives a detection index of 313 meters. The Canadian experiments were conducted in a Pacific West Coast coniferous forest. Manson (2009) also carried out a sound experiment in the Pacific West Coast coniferous forest in a recent study. This study reported both maximum and minimum attention ranges. The minimum attention getting range was a subjective measurement determined by the searcher. Depending upon the whistle type and season this ranged from 200 to 400 meters for alerted searchers. While maximum ranges do not convert to an ESW value the general range is similar.

One important finding of this paper was the observation that in many cases the subject detected the search team without the searchers detecting the subject. The experiment protocol was for a single verbal reply and for the subjects to stay in one place. In reality a missing person would most likely try to move towards the team and shout multiple times. Operationally teams would be well advised to make sure they spend sufficient time listening for a response. Those venturing into the woods are also well advised to carry a whistle and light source.

One challenge of this research was to adapt the specifics of experimental design and analysis for the specifics of sound-light line and sweep. This required direct observation of the techniques being taught and conducted by actual practitioners in the appropriate environment. This was accomplished by conducting and attending field trials, refresher courses, and field demonstrations prior to establishing the methodology. In addition, extensive conversations were conducted with knowledgeable searchers, including and going beyond the SARINZ instructor pool. This allowed for the development of the specific methodology.

The changes in methodology from previous visual methods included; marked cones every 100 meters, a modified AMDR procedure, use of trained searchers as the search subjects, use of un-alerted subjects and searchers, clear difference in signals generated by searcher and subject, creation of detection log, and measuring wind speeds at every detection opportunity. These changes were viewed as successful. In fact, this was the first auditory detection experiment where both the subjects and searchers were not alerted. As a result it was possible to document cases where the subject heard the search team, but the search team did not hear the response.

Previous visual experiments had used data collectors that were not part of the experiment staff. These "volunteer" data collectors often collected more data than needed (making scoring a little bit more difficult) but fortunately seldom left out critical information. This was the case with the sound-light experiments. All of the data collectors were searchers themselves. Almost all of the searchers successfully completed the data collection log. Only one team neglected to record the time at each cone. While the team's detections were logged, it was impossible to score the team for subject's hearing the team. This problem could easily be remedied by spot checking the logs early on in the track by a member of the experiment staff. Using searchers as data collectors was a success overall.

As a "pilot" experiment several important factors have been identified that could improve future experiments. Two key variables were not controlled. Searchers were allowed to use whatever whistle and torch (flashlight) they normally used. It was noted anecdotally that the type of whistle and torch did make a significant difference in detections. This is well worth further experimentation. Some other sources of improvement include; conducting experiments in different terrain (such as flat terrain, valley bottom, etc.), conduct experiments in different types of vegetation or times of the year, conduct experiment to quantify potential correction factors (wind, background noise, precipitation, temperature, hearing loss, etc.), better measure participants hearing ability, record AMDR values for auditory, whistle, and torches, update IDEA, issue radios to all subjects and obtain location coordinates immediately, create a subject debriefing form, use synchronized time (available from GPS receivers), use GIS software for measurements versus Google Earth, and have staff spot check detection logs early in the experiment.

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Time Required For a Drowning Victim to Reach Bottom

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Abstract

This paper describes a mathematical model that can be used to provide an estimate for the amount of time a drowning victim takes to sink through the water and hit bottom, including a table for drift during the descent. A victim may be on the surface and then be on the bottom less than 10 seconds later. Search and rescue professionals need to be trained to understand the short time during which a victim can sink and drown and the need for immediate search and rescue from the bottom starting at the last point the victim was seen.

KEY WORDS: Rescue, Drowning, Lifeguarding, Body Retrieval

Introduction

How many times has a rescue squad come to a waterfront and heard the family say, "We just looked away for a second and he was gone." A common misconception is that a swimmer will stay on the surface struggling and then slowly sink beneath the surface of the water. They mistakenly believe that a witness will easily have enough time to see the drowning and make a rescue.

The purpose of this paper is to describe a mathematical model that can be used to provide an estimate for the amount of time a drowning victim takes to sink through the water and hit bottom. Since this is a model and not a full simulation, the number of variables used in the model has been limited to weight, chest circumference, chest length and water depth. Timed experiments were done by the authors in a swimming pool where one of the authors swam to about a six foot depth, expelled air, became negatively buoyant and sank to the bottom of the pool. The results of these simulations were used to check if the calculated results were close to the experimental results.

As with any mathematical model there are serious differences between the model and what actually occurs in a real situation. The intent of the model is not to arrive at an exact time but rather to show an estimation of the very short duration required while sinking. Issues which can affect the sink time include such issues as body density which differs with factors such as age and body type, current flow, and density of the water. As an example, salt water has a higher density than fresh water and therefore will have an impact on sink time. Continuing this example, a very fit twenty year old male will sink faster in fresh water than a very young female in salt water.

Since it will be shown that the time to reach bottom is relatively short (in seconds), the implication for search and rescue personnel is that a victim may be on the surface at one point in time, but be on the bottom 5-10 seconds later. Additionally, the fastest recorded drowning the authors have analyzed, i.e., time elapsed between the victim's head going under water and CPR being started immediately without the victim recovering, is 38 seconds (Hunsucker & Davison, 2010). There has been at least one other drowning documented by the authors that was less than one minute in addition to several that were felt to have been less than a minute but lacked sufficient documentation to verify the time. Unless a fellow swimmer or lifeguard, if there is one, is both vigilant and able to detect the visual signals showing a swimmer in trouble (Hunsucker & Davison, 2008) the fast drowning and sinking can make it easy to miss a victim after they disappear from the surface of the water.

It should also be remembered that, based on the laws of physics, drowning victims do not go part way down and stop once they lose positive buoyancy. They go all the way to the bottom. Emergency personnel need to be aware that drowning victims are either on the surface, moving quickly (in seconds) toward the bottom or on the bottom.

The Basic Formulas

Archimedes' principle states that a body is buoyed up by a force equal to the weight of the water that the body displaces. Since fresh water weighs approximately 62.4 pounds per ft^3 , we have the Buoyant Force, F = 62.4 lbs x V, where V is the volume of the victim in cubic feet. If F, the buoyant force, is larger than W, the weight of the victim, the victim will float. Otherwise, the victim will sink. Since the probability that they are equal is zero, a body either floats or sinks.

We make a few assumptions about the body's shape in order to build a model that can be used for estimation purposes. Suppose the chest where the buoyant force is concentrated has a height *h* and a circumference *C* and is roughly cylindrical in shape with radius *r*. This air cylinder is what we suppose changes with inhalations. Since the volume of the air cylinder decreases with exhalation, the volume will change and thus the buoyant force will change. Once we know the change in volume, we know the change in the force, then using F=ma, we can solve for the time, *t*, using elementary calculus.

The following formulas relate circumference to radius and then radius to volume for a cylinder.

Formula 1: $r = \frac{C}{24\pi}$ where *C* is given in inches and r in feet.

Formula 2: $V = \pi h r^2$ where *h* and *r* are in feet and *V* is given in ft^3

Now let C_1 and C_2 be the starting and ending circumferences of the air cylinder respectively. Here we assume that C_1 is the air cylinder circumference at the point where buoyant force and gravitation force are equal.

Then, using V for the change in volume, the change is given by

Formula 3: $V = \pi h[r_1^2 - r_2^2] = \frac{h}{\pi 24^2}[C_1^2 - C_2^2]$ in cubic feet.

So the change in force is given by 62.4 x V and also by "(m) x (a)" where m is mass and a is acceleration. So $a = \frac{32x62.4xV}{W}$ where *W* is the weight of the victim.

Letting s = the depth of the water and using elementary calculus $s = \frac{at^2}{2}$. Substituting *a* and *V* from above and solving for *t* yields

Formula 4: $t = \frac{1}{31.6}\sqrt{\frac{sW}{V}}$

Formula 5: $t = 1.346\sqrt{\frac{sW}{hC_1^2 - hC_2^2}}$ where t is given in seconds.

s - Depth of the water in feet
W - Weight of the swimmer
h – Height of the chest or air cylinder in feet
C_1 – circumference of chest after inhalation in inches
C_2 – circumference of chest after exhalation in inches

Examples

The chest measurements used in these examples were done on individuals known to the authors in order to approximate the variables such as air cylinder height and the change in volume with exhalation. The reader is encouraged to measure a few people and calculate their own times

One

Suppose that the victim weighs 150 pounds, the air cylinder changes from 43 inches to 42 inches, the height of the air cylinder is 1 foot and the depth is 8 feet. Then t = 5.06 seconds.

Two

Suppose that the victim weighs 75 pounds, the air cylinder changes from 23 inches to 22 inches, the height of the air cylinder is 0.5 foot and the depth is 8 feet. Then t= 6.95 seconds.

Three

How much change in circumference will result in a 10 second descent? If we use the data in example one and suppose that the resting circumference is 42 inches, we ask how much did the chest have to deflate in order to have this time of transition. Plugging into the formula and solving yields $C_1 = 42.26\ inches$. So it would take only a quarter inch change in chest circumference to get a time as long as 10 seconds.

Four

To show a range of sink times we went to several anthropometric tables and size studies (Department of Defense, 1991) (Kuczmarski et al., 2002), (Moll & Wright, 2004), (Snyder, Spencer, Owings, & Schneider, 1975) to find typical sizes for different ages.(See Table 1) Looking at the average torso length for a male from waist to shoulder of 14.8” and an average height of 5’9” we use h=21% of height or 14.5”. While not a precise measurement, this is close enough for estimation purposes. We also suppose only a 2% increase in chest size with an inhalation. This is a relatively small increase as an increase of well over 10% is common. Making these assumptions leads to the following table for estimated sink times for 8 feet deep.

Table One Estimated Time to Sink Eight Feet				
Age	Weight(lbs)	Chest Cir. (in.)	Height	Sink Time (sec)
3	33	20.2	2’9”	7.1
6	48	22.8	3’6”	6.4
12	95	28	5’	6.2
Men	180	43	5’9”	5.3
Women	148	40	5’4”	5.1

Experimental Results

Every good theory should have some applied application to verify the reasonableness of the theory. Using one of the authors as a test subject, an air tank with a long hose on a regulator was placed on the deck. The test subject weighed 240 pounds, was 6 feet tall and was in 5.5 feet of water. Enough air was exhaled until positive buoyancy was lost and the descent was timed until the bottom was contacted. This was repeated 10 times. The average time to bottom was 5.0 seconds with a standard deviation of 0.58 seconds. The times ranged from 4.0 seconds to 5.9 seconds. The variation in times is explained by the variable amounts of air exhaled resulting in variable decreases in air cylinder circumference.

For a subject whose chest decreased from 49 to 48 inches, who weighed 240 pounds and who was in 5.5 feet of water, our model yielded an approximate sinking time of 4.9 seconds. Thus we see a reasonable agreement between the theoretical and the experimental results.

Discussion

There are several factors which can cause the time to decrease. In our model, we have assumed that the body goes to the bottom in a horizontal position as what (we what) was calculated was for when the center of gravity of the body would hit the bottom. Since the center of gravity is located in the pelvic region and the center of buoyancy is located in the mid chest region, there is a turning moment placed on the body. As the body sinks, the victim will come to a more upright position as the two forces of buoyancy and gravity attempt to line up. This will cause the feet to hit the bottom first. This in essence shortens the distance to the bottom and thus the time. Once this happens, the body will gradually sink into a more horizontal position. A common sinking sequence is to have the feet contact the bottom, then the lower leg. Sometimes the torso will be slightly elevated due to the presence of air in the upper body region. The head will hang down and the arms will either sink or float up a bit depending on the physiological characteristics of the body. Over time, as air continues to evacuate the body, the body may sink to a point where most of the body contacts the bottom.

Another factor which may well shorten the time to the bottom is if water replaces air space in side the victim. If water fills the mouth, throat, lungs, stomach or any other internal air cavity of the victim, then the buoyant force will be decreased as will the time to the bottom.

This model was developed primarily around water that was eight feet deep. Deeper water would, of course, lengthen the sink time and the corresponding drift distance that the body will move. Said another way, the deeper the water and the faster the flow then the longer the drift distance and sink times.

In Table One, we assumed a minimal chest circumference loss of only 2%. Greater losses would of course account for more rapid sinking. These readings have a several implications for search and rescue.

The first implication is that any lifeguard or fellow swimmer needs to be vigilant and be able to recognize the signs that a swimmer is in trouble at the surface because once a drowning victim begins to sink, they are quickly going all the way to the bottom. Once they are on the bottom, it is difficult to determine where they are from the surface. Often, the only indications that the swimmer is on the bottom (if you can see the bottom) is a color variation, (This is referred to as a “smudge”, since water variables such as glare, clarity, surface action, or siltation tends to mute colors and distorts shapes. Only under the best of circumstances will a victim on the bottom appear to be a person or will different colors be obvious – hence a subtle color variance, a smudge), the patient’s body in a temporary tilted position with knees on the bottom (again, if the water is clear enough to see a body), small bubbles at the surface, or a vomit stream at the surface.

The second implication for search and rescue is that the very quick transition from on or near the surface to the bottom means that the victim’s body is less likely to drift or move far away. Even in a current, once the victim comes to a hole or eddy, they tend to stop. Holes and eddy’s on the bottom of lakes and rivers tend to keep what is in them. This implies that the victim has a good chance of being found on the bottom at or close to the place they were last seen on the surface. One exception to this is if a victim falls into a storm sewer or man-made flood system where there is a lot of moving water and smooth sides and bottom. The body then tends to roll and may end up far downstream. The same situation can occur with the extreme current flows often found in flooding situations.

The third implication is that the current in a river can move the body downriver while it is sinking to the bottom. Lakes and swimming pools don't normally have currents. Many recreational rivers only have a current of 2-3 miles per hour while a fast river may reach 6-7 mph. A fast stream may only be flowing at less than 1 mph. (Marietta, 2012) The rapids above Niagara Falls run about 25 mph. (Niagara Parks, 2012) You can estimate how many feet a body might move in a river if you find the speed of the current and multiply by the number of seconds the body takes to sink. The conversion from miles per hour to feet per second can be done by multiplying miles per hour by 88 and then dividing by 60. Table 2 shows how far a body may move in various currents during the descent. As an example, in a fairly common flow of 2 mph, a body will move between 11.7 and 20.5 feet downriver before contacting the bottom, assuming a 4 to 7 second sink time. Once the bottom is contacted, downriver movement will be minimized by irregular bottom contours. Regardless of the current flow, Table Two emphasizes the point that body searches should begin in the immediate vicinity of the best estimate of the point the victim was last on the surface.

Table Two
Distance (ft.) moved during descent for various currents

		Speed (mph)						
		1 mph	2 mph	3 mph	4 mph	5 mph	6 mph	7 mph
Time (sec)	1	1.5	2.9	4.4	5.9	7.3	8.8	10.3
	2	2.9	5.9	8.8	11.7	14.7	17.6	20.5
	3	4.4	8.8	13.2	17.6	22.0	26.4	30.8
	4	5.9	11.7	17.6	23.5	29.3	35.2	41.1
	5	7.3	14.7	22.0	29.3	36.7	44.0	51.3
	6	8.8	17.6	26.4	35.2	44.0	52.8	61.6
	7	10.3	20.5	30.8	41.1	51.3	61.6	71.9
	8	11.7	23.5	35.2	46.9	58.7	70.4	82.1
	9	13.2	26.4	39.6	52.8	66.0	79.2	92.4
	10	14.7	29.3	44.0	58.7	73.3	88.0	102.7

Many search and rescue organizations have recognized this phenomenon. For example, see Cynthia Garfold's article on "The Biology of Drowning" from the Western Pennsylvania Search and Rescue Development Center for an excellent description of how and why bodies tend to stay close to where they went below the surface. She wrote, "When a drowning occurs in a river, the most common mistake is to search for the body too far downstream." (Garfold, 2009)

However, there are many factors which could increase this drift by significant orders of magnitude. Two of the factors which will have a major impact are current flow and river contour. Extreme currents such as those encountered in a flooding or even in naturally flowing rivers have been known to move bodies miles from the location of the actual initial immersion. In addition, a smooth bottom or regular bottom such as found in a channelized flow produces little, if any, bottom eddies that will slow the drift of a victim. There are numerous examples of drowning that can be found in the press that show the impact of extreme current on drift. For example: 1) Lake–"yards away" drift (The Times-Picayune, 2012), 2) Lake–"near" drift (WishTV, 2012) 3) River–"250 yard" drift (DesMoines Register, 2012) 4) River–"approximately 300 yards drift" (Fox19, 2012) 5) River–"quarter mile" drift (Associated Press, 2012), 6) River-"two mile" drift (Seattle Times, 2012).

Conclusion

While this model does not yield a formula that shows as precise a time as a more sophisticated simulation would, it does show an approximate estimate of the time to the bottom. More importantly, it shows that the time to sink to the bottom is fairly short. Different combinations of variables show times of less than 7 seconds for sinking and only extremely small chest size changes could increase the time to as long as 10 seconds. This model provides an estimate of where to begin the search. Other factors such as water depth, current flow, body type, and water density should be considered which may lengthen the sink time and promote extended movement of the body.

The major implication for search and rescue and for body retrieval is to initiate the search at the point where the victim was last estimated to be at the surface.

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Analysis of urban search and rescue markings applied following the 22 February 2011 Christchurch earthquake

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Abstract

In one of New Zealand's worst disasters, international rescue teams from around the world responded to the Christchurch earthquake. To ensure interoperability and effectiveness of such global rescue responses, an international body under the auspices of the United Nations has established guidelines for these rescue teams, including a standardised search marking system for damaged and collapsed structures. The aim of this research was to evaluate whether responding teams adhered to the guideline when applying such markings. From hundreds of photographs, 153 images were visually analysed using a novel qualitative evaluation tool known as the Search Marking Adherence Score (SMAS). An online survey of responders (n=68) gathered further qualitative and further quantitative data. It was found that search markings were generally well applied but some team types performed better than others. New Zealand Response Teams scored the highest, followed by International teams, then New Zealand Task Forces. The analysis also leads to several practical recommendations to enhance the search marking specifications within the international guideline.

KEY WORDS: *Christchurch, earthquake, urban search and rescue, INSARAG, SMAS, markings, New Zealand.*

Introduction

At 12:51pm on Monday 22 February 2011, a shallow magnitude 6.3 earthquake struck at the heart of the Christchurch, leading to 182 fatalities, hundreds of injured (Royal Commission of Inquiry: Canterbury Earthquakes, 2011), over 156,000 insurance claims and damages in excess of NZ$5bn (Murdoch & Fraser, 2011) making it one of New Zealand's worst disasters in history. The earthquake left hundreds of buildings severely damaged with people trapped inside. This led to New Zealand's first national state of emergency being declared (Carter, 2011) and prompting a massive international urban search and rescue effort with teams afar as the United Kingdom, United States of America, Japan, China, Taiwan, Singapore and Australia deploying to assist (Figure 1).

Figure 1: Map of countries that deployed international rescue teams to Christchurch earthquake (Map source: Google).

The formal global mechanism to standardise such response efforts is provided by the United Nations through guidelines established by the International Search and Rescue Advisory Group (INSARAG) under the authority of United Nations General Assembly Resolution 57/150 (United Nations General Assembly, 2002b) of which New Zealand was in favour of (United Nations General Assembly, 2002a). INSARAG published guidelines include capacity development, standardised tactics, search methodology, team classification and search marking systems. In 2001, New Zealand formally established the national urban search and rescue project (National Urban Search & Rescue Steering Committee, 2008) which gave effect to the resolution. The multi-agency Steering Committee included officials from the Ministry of Civil Defence & Emergency Management, New Zealand Fire Service and local government. Over the following years, urban search and rescue task forces were established (NZTF1 in Palmerston North, NZTF2 in Christchurch and NZTF3 in Auckland) by the New Zealand Fire Service. These taskforces were augmented by the development of locally based volunteer civil defence rescue teams nationally audited and registered as New Zealand Response Teams. Following the February 2011 earthquake all three task forces and eighteen response teams were deployed to the affected area, making it the largest national disaster rescue deployment in New Zealand history. The central business district was one of the worst affected areas and became the focal point for rescue personnel to search some 4,000 buildings in the cordoned zone, later to be known as the *Red Zone*. In accordance with the INSARAG Guidelines and Methodology (herein the guidelines) a structural marking (figure 2) is applied to collapsed structures (United Nations, 2011, p. 95). This marking is different to the disaster rescue markings (figures 3 and 4) used in the United States of America as specified by the Federal Emergency Management Agency (2003b). The guideline has been continually updated through input at annual INSARAG Team Leader Meetings and prior to the February earthquake the Victim Marking system (figure 5) was removed (T. Skavdal, INSARAG Secretariat, personal communication, October 2011). Indeed the victim marking concept was not included since the July 2006 edition of the guideline, but published in the General Rescue Manual of March 2006 (Ministry of Civil Defence & Emergency Management, p. 33). The purpose of the marking systems is to provide a standardised method to indicate search progress and to clearly indicate whether potential or actual victims remain inside the collapsed structure to avoid duplication of search effort and prevent heavy machinery being accidentally used where casualties remain. It is important that all responding agencies understand the marking system along with other protocols outlined in the guideline to avoid confusion. Beyond the work of Morris (2007), there is a void of empirical research relating to INSARAG activities. No empirical research could be found relating to the FEMA marking system either. This study explores the application of the INSARAG structural markings used following the February earthquake through evaluating quantitatively the adherence to the guideline using a newly developed tool, evaluating qualitatively the rationale for adherence variation by responders through an online survey and offers an appraisal and recommendation for future application of disaster search markings.

Figure 2: INSARAG Structural Marking

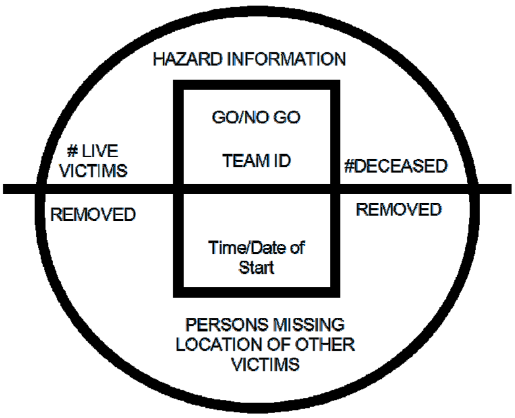

Figure 3: FEMA Structure/Hazards Evaluation Marking

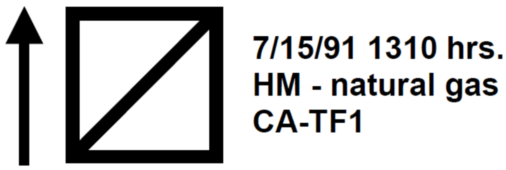

Figure 4: FEMA Search Assessment Marking

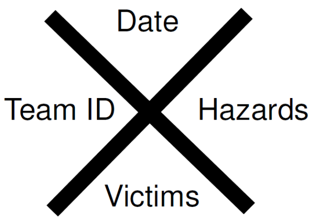

Figure 5: INSARAG Victim Marking (discontinued)

Method

A sample of images (n=153) containing search markings applied within the following ten days of the 22 February earthquake were finalised from several hundred photographs supplied by social media and other network requests, along with images from the internet. The majority were geotagged or displayed adequate building features to allow confirmation that they were from the affected central business district. According to the Canterbury Earthquake Recovery Authority (CERA), there are approximately 4,000 buildings in the central business district. Images were visually assessed and given a Search Marking Adherence Score (SMAS) and additional data was also captured. The qualitative data results have a margin of ±7.77% at the 95% confidence level based on the sample (n=153) and population (n=4,000) sizes. Following the analysis of SMAS data, an online survey was completed.

Search Marking Adherence Score

A simple quantitative grading system was developed as part of this research project to enable comparative analysis of search markings applied following the February earthquake. The common characteristics of search markings between the INSARAG structural assessment and the FEMA markings (Structural/Hazard Evaluation Marking when used in conjunction with the Search Assessment marking) were identified (table 1). Based on these common characteristics, the Search Marking Adherence Score (SMAS) (table 2) is then applied to images of search markings. The simplicity of the tool enables benchmarking of search markings to occur. In operating the tool, SMAS is converted to percentage, excluding criteria unable to be evaluated. Fields that are unable to be evaluated are counted and noted next to the percentage as the adjustment factor in superscript i.e. "SMAS: 85%^{2}"

Characteristics	**FEMA**	**INSARAG**
Colour	International Orange	International Orange
Size	2'x2' (0.6m x 0.6m)	1m x1m
Placement/Positioning	SHE specified only	Near point of entry
Usage	FEMA teams	USAR teams
Entry Recommendation	SHE	Go or No Go
Reporting	Yes - To local ICP	Yes to OSOCC
Team ID	Yes (US as per FOG)	Yes
Date/Time Start	Time	Yes
Date/Time Finish	Yes	Yes
Hazard Info	Yes	Yes
Missing Persons	Yes	Yes
Live Victims Rescued	Living – only still inside	Yes
Dead Victims Extricated	Dead – only still inside	Yes
Completed to Capacity		Circle around entire marking
Confirmed as Clear		Horizontal Line

Table 1: Common characteristics of search marking systems

The Search Marking Adherence Score (SMAS) was peer reviewed then piloted and refined with a small sample (n=20/13%) before being applied to the entire sample.

Criteria	**Major Non Adherence (1)**	**Minor Non Adherence (2)**	**Adherent (3)**	***Example***
1. Colour (compulsory)	Difficult to read	Colour choice able to read	International Orange	*3 (International Orange)*
2. Size (compulsory)	<20% 1x1m UN 2'x2' FEMA Or no box	±5-20% 1x1m UN 2'x2' FEMA	>5% 1x1m UN 2'x2' FEMA	*2 (1.2x1.2m)*
3. Placement/Positioning	Not on Structure	On Structure	Front of Structure	*2 (side of structure)*
4. Entry Recommendation	Well outside specification or Incorrect location or not included	Correct location and near specification (N or NG)	Correct location and within specification	*2 (NG, rather than No Go)*
5. Reporting	Not reported	Reported outside parameters (delayed)	Reported within parameters	*- (Blank/unable to verify)*
6. Team Identification	Unable to Identify country or team	Difficult to Identify country or team	Easy to Identify country or team	*3 (NZ-RT23)*
7. Entry Time	Well outside specification or not given	Near specification	Within specification	*1*
8. Exit Time	Well outside specification or not given or unable to read	Near specification	Within specification	*3 (Date given 22FEB 13:15)*
9. Hazard Info	Well outside specification or unable to read	Near specification	Within specification (including Null)	*- (Blank)*
10. Victim Data	Well outside specification or unable to read	Near specification	Within specification (including Null)	*3 (0 on left and right of box)*
11. Completed to Capacity	Well outside specification	Near specification	Within specification	*3 Box circled*
12. Confirmed as Clear	Well outside specification but noted otherwise	Near specification	Within specification	*3 Line through box*

Table 2: Search Marking Adherence Score (SMAS)

Limitations

The SMAS is limited to generating quantifiable data on the adherence to either the FEMA or INSARAG marking system. It is not capable to measure rationale for deviation, so therefore it provides a score solely on adherence to the criteria, as opposed to acknowledging the operational demands may require such non-adherence. To capture the rationale for non-adherence, an online survey was undertaken to ascertain the rationale for deviation from the guideline. The sample size when viewed collective provides a fair margin of error. The population size is likely to be exaggerated in this study as not all buildings within the Central Business District would require a search marking under the guideline and by doing so the results may have a lower margin of error accordingly. There are however limitations with the data; in particular low daily samples at the beginning and end of the date range in particular days 1 (n=2), 2 (n=3), 9 (n=5) and 10 (n=1). Individual teams or countries were unable to be negatively identified as part of the ethical requirements for this study, consequently a number of images have their team identification removed. This limits segregation of results to allow comparison between individual teams and data is based on three team types, rather than specific entities.

Results

General Observations

Of the sample population (n=153), 66.01% of the markings were applied by International Teams, 24.84% by NZ Task Forces and the remaining 9.15% were applied by NZ Response Teams. No markings by other team types such as New Zealand Fire Service (Non-USAR), Red Cross or Land Search and Rescue were observed. Only 1 (0.65%) marking was identified to have followed the FEMA marking system, which was applied by a NZ Task Force. 24.84% (n=38) used the figure zero to indicate a null field (figure 8).

Search Marking Adherence Score

There was an overall trend of improvement of search marking adherence as the incident progressed (figure 6). The Quantitative data in isolation does not provide any valid explanation for the minor increase in the scoring trend. Results from the survey shall be used to in conjunction with this data to make an informed analysis.

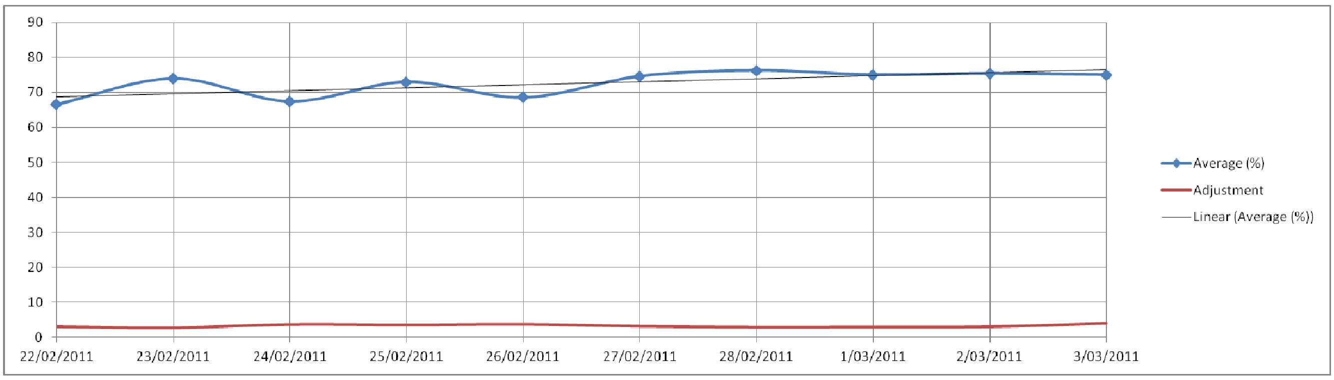

Figure 6: SMAS trends

SMAS Criteria comparison by Team Type

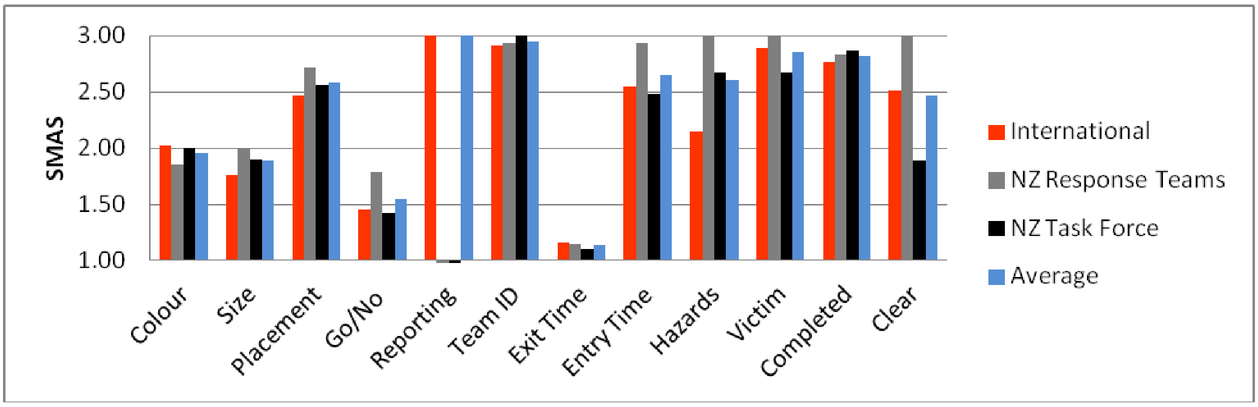

Figure 7: SMAS average by team type

In analysing the colour application of the sample, only 4% (n=6) used the specified *international orange* colour to apply the search marking. The next prevalent colour selected was other shades of orange, including fluorescent types (40%, n=61) meaning 44% (n=67) of all search markings were a shade of orange. Following orange types, pink (39%, n=59) appeared to be the closest rival. Other colours included yellow (8%, n=13), red (5%, n=8) or green (4%, n=6). No other colours were observed in the sample. In respect to the SMAS *colour* criteria (figure 7), international teams averaged 2.02, NZ Task Forces 2.00, NZ Response Teams 1.86, with an overall average of 1.96.

In the scoring of *size* (figure 7), the international teams slightly under performed under these criteria (1.76) against their NZ Task Force (1.89) and NZ Response Team counterparts (2.00) with an overall average of 2.00. An illustration of a marking being oversized is provided in figure 10.

Placement scores also hard marginal variation with NZ Response Teams having a high adherence to the guideline (2.71). Remaining team types followed with NZ Task Forces (2.55), International Teams (2.47) and an overall average of 2.58. In application of the markings, 80.39% (n=123) were applied on the collapsed structure near the point of entry in accordance with the INSARAG guideline. The remaining markings were applied to the fence 6.54% (n=10), footpath 10.46% (n=16) (figure 11) or on a sheet or similar non structural element 2.61% (n=4).

Scoring of *Go/No Go* criteria showed a distinctive variance between NZ Response Teams (1.79) and International Teams (1.45) and NZ Task Forces (1.42), with an overall average of (1.55). The guideline requirements specified in F13.6 (United Nations, 2011, pp. 95-96) both in the text descriptor and example illustration clearly prescribe “Go” or “No Go”, however International and NZ Task Force team types were more prone to abbreviate these to “N” or “NG” (figure 9).

Reporting was difficult to accurately score as it was not possible to interview each person responsible for the sampled marking to ascertain whether the assessment result was reported immediately to the

OSOCC as specified in the guideline (United Nations, 2011, p. 95). Only one confirmed instance of reporting assessment result from the image sample population was available. Although the SMAS does take into consideration all criteria of the INSARAG structural marking, this criteria was omitted under the Adjustment Factor in close to all instances (99.34%) under this analysis.

All team types consistently scored high under the *Team Identification* criteria. NZ Task Forces scored the maximum average of 3.00, followed by NZ Response Teams (2.93) and International Teams (2.91) with an overall average of (2.95) making it the most highly scored criteria across SMAS analysis. There appeared to be no major issues with identifying the team whom applied the search marking.

Entry and *Exit Times* were problematic with discrepancies within the guideline. The guideline requires a start (entry) date and time under F.13.6(3.4) and a finish (exit) date and time under F.13.6(3.5), however the example illustration only provides for start time/date, no finish date/time is provided (United Nations, 2011, p. 96). Based on example illustration within the guideline, where only one date/time was provided, it has been assumed as the *start* date and/or time. Due to this there was significant underperformance of *exit* criteria across all team types (International 1.16, NZ Response Teams 1.14 and NZ Task Forces 1.11) with an average of 1.14. In contrast, the use of at least an *entry* date or time in the image sample was very high (average 2.65) with NZ Response Teams being scoring highly (2.93). International Teams (2.54) and NZ Task Forces (2.47) following behind. 10.46% (n=16) of markings used the US date format system (figure 8) contrary to local format and all of the US date formats were applied by International Teams.

Hazard information scores varied considerably from 3.00 (NZ Response Teams), 2.67 (NZ Task Forces) and 2.14 (International Teams), average 2.60. Figure 10 illustrates on example of incorrect placement of "water basement" hazard information which should have been outside the box at the top if to applied in accordance with the guideline (United Nations, 2011, p. 96).

Figure 8 (International Team): *Example of foreign date format. The size and location of the date is also non-compliant. Zero fields for victim information are also applied. Photo by Stuart Fraser.*

Figure 9 (NZ Task Force): *Example of abbreviated Go/No Go, correct placement of hazard information, limited date/time, and incorrect indication of "clear" (line through marking not applied). Photo by Stuart Fraser.*

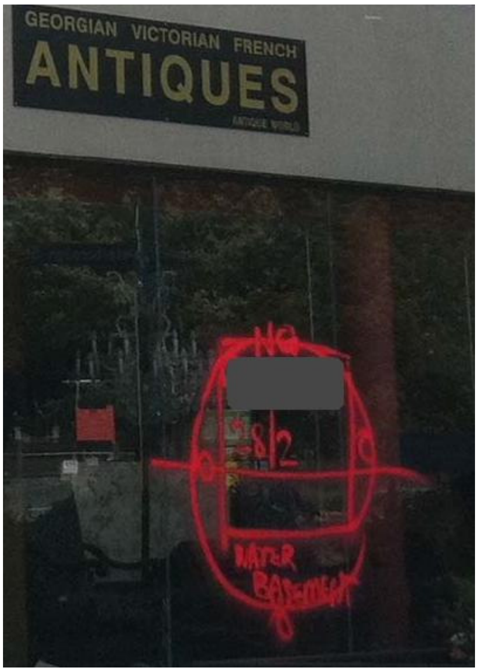

Figure 10 (International Team): *Marking that misplaces and abbreviates "No Go". Incorrect placement of "water basement" hazard. Zero fields for victim identification are also applied. Photo by Peter Seager.*

Figure 11 (NZ Response Team): *Marking applied not on the structure, abbreviated "Go" and oversized. Note use of letters to denote month to avoid confusion with foreign date format. Horizontal line drawn through marking to mark as clear. Photo by Alan Keeber.*

Victim Data adherence scored well with an overall average of 2.85 (NZ Response Teams 3.0, International Teams 2.89, NZ Task Forces 2.67). The use of the figure zero used (24.84%, n=38) to indicate a null field was mainly used by international teams and predominantly for victim data (figures 8 and 10). Despite the removal of victim markings (figure 4) from the guideline prior to 2006, there appeared to be a trend for some teams, both domestic and foreign to still apply these (Figures 12 and 13).

Figure 12. *Victim marking. Photo by NZ Defence Force.*

Figure 13: *Victim marking. Photo by Phil Parker.*

All team types generally adhered to the guide to mark a structure as *Completed* (NZ Task Forces 2.87, NZ Response Teams 2.83, International Teams 2.76. Overall average 2.82). Again between 2002 and 2006, there appeared to be another change to the guideline introducing a horizontal line to indicate as *Clear*. The difference being that *Completed* was to indicate that the structured had been searched to the team's capacity and indicated by a circle being drawn around the entire marking (United Nations, 2006, p. 96). The new marking to confirmed no more victims remain (or *Clear*) was the addition of a horizontal line through the entire marking (United Nations, 2006, p. 96). There appeared to be significant variation in adherence to the guideline by teams marking a structure as *Clear*. NZ Response Teams showed high adherence to the guideline for confirming a structure had no more victims remaining (3.00), followed by International Teams (2.52) and NZ Task Forces (1.89).

Although the research will not negatively identify specific task forces, during the analysis of pictures it was observed that the Singaporean and Australian international teams scored very high in their adherence to the INSARAG guideline.

Overall, NZ Response Teams had the highest adherence to the guideline with an average SMAS of 77.46%$^{3.36}$, followed by International Teams 71.55%$^{3.38}$ and least adherent was NZ Task Forces 69.87%$^{3.32}$ (SMAS Average across all team types 73.00%$^{3.35}$,n=153).

Survey

An online survey was then undertaken to address areas that required further clarity arising from the SMAS evaluation. Responding teams were approached via direct email and social media channels, with all foreign INSARAG teams being approached to participate through their respective country focal points. There were a total of 68 responses to the online survey from an estimated population of 600 responders (both domestic and international) providing a margin of error ±11.1% at the 95% confidence level. Non-accredited responders were not solicited as part of the survey.

Team Origin

The survey respondents comprised of New Zealand Task Forces (4.7%, n=3), New Zealand Response Team (18.8%, n=12), New Zealander Other (7.8%, n=5) and International (68.8%, n=44). The majority of the International team origins were Australian. The lack of New Zealand Task Force participation could be attributed to ongoing industrial action including prohibition of union members to use computers.

Experience and Qualification

The majority of respondents deemed their level of training to be certified to INSARAG Heavy (60%, n=33), followed by NZUSAR Responder (30.9%, n=17). Other respondents selected nil (1.8%), NZUSAR Awareness (1.8%), NZUSAR Technician (3.6%), INSARAG Light (1.8%) and INSARAG Medium (3.6%). This data is consistent to the team origin data above. The experience base within the sample population was high with the majority indicated they had more than five years experience (74.2%, n=49), including 27 that had more than ten years experience (40.9%). In respect of the actual response to major structural collapses, the majority had no experience (40.9%, n=27), only 1-0 days (40.9%, n=27) and only (18.1%, n=12) having 11 or more days experience at such events. In correlation with the experience base, it would appear that the majority of USAR operatives who deployed to Christchurch generally have minimal operational experience in structural collapse operations which is likely to be attributed to the fact that urban search and rescue is relatively new within Australasia with most capacities only formally established within the last decade.

Familiarity with and importance of INSARAG Guidelines

Despite the expectations laid out in United Nations General Assembly Resolution 57/150 (2002b), respondents largely appeared unfamiliar with the “INSARAG Guidelines & Methodology”, with 24.2% (n=16) never heard of the document, 19.7% (n=13) aware of its existence but never read the document, with the majority having read it (entirely or in part) only 1-2 times (34.8%, n=23). It could be argued that national documents such as training packages disseminate the core information such as search marking systems, however the SMAS analysis and later surveyed questioning around guideline version updates would suggest otherwise. When asked how important it is for teams to apply the INSARAG markings in accordance with the guideline, 98.3% (n=57) indicated compliance was moderately to extremely important (66.7 % extremely important, 29.8% very important, 1.8% moderately important).

Perceived practicality of INSARAG search markings

It has long been of concern by some practitioners that the INSARAG marking's size and colour was impractical. The earlier SMAS analysis indicated only 4% of the sample pictures used the prescribed international orange colour (figure 7). Respondents were asked how practical was the use of the colour "international orange" for search markings applied during the response to the Christchurch earthquake. 64.9% (n=37) indicated this colour was practical or highly practical; 29.8% (n=17) indicated it was not practical or highly unpractical. Many respondents also commented that the colour selection itself was not the issue, but the lack of availability of the prescribed colour in sufficient quantities in the initial phase of response. The one by one metre box used as part of the structural marking (figure 2) was also evaluated for perceived practicality. 61.4% (n=35) indicated the box size was practical or highly practical. 31.6% (n=18) indicated it was not practical or highly unpractical. As the INSARAG guideline has an international audience, the impact of varying date formats was also surveyed. 42.1% of respondents (n=24) indicated that the varying date formats (i.e. 2/21, 21/2, 21 FEB etc) by international teams was problematic. It could be assumed that under the guidelines, international teams need to respect local traditions and customs, including adopting the local country's date formatting convention – this however was not always the case.

Awareness of changes to INSARAG search markings

Respondents (n=57) were asked to best describe how to illustrate that all work has been completed and no victims (live or deceased) remain on an INSARAG structural marking. 47.4% (n=27) correctly identified the correct action, that being to draw a horizontal line through the box. 40.4% (n=23) chose to draw a circle around the box, which used to be the correct answer prior to the 2006 edition of the guideline. 12.3% (n=7) also gave incorrect answers, choosing writing "clear" or "0" underneath the box. This supports the earlier SMAS analysis which suggests significant misunderstanding of the completion to capacity and final clearance markings. Ironically, it is the New Zealand Response Teams who are not linked into the INSARAG arrangements that scored the highest SMAS scores and understanding of the current version's requirements in the survey results. Additionally, some respondents also noted that the horizontal line should also be changed to indicate that not only has the building been cleared, but there should be no need for rescue personnel to re-enter the structure.

General Comments

Respondents also commented on the comparison between the FEMA and INSARAG marking systems. Users including those who were familiar and experienced with the FEMA marking, indicated a preference for the INSARAG structural marking as it provided for more information, although the prescribed size is too small to be useful. There was also demand for a rapid clearance marking that could be applied quickly to non-structural search areas such as vehicles, boats, caravans, collapsed walls and sheds by first responders. This was reflected by one respondents comment:

"I believe they [the marking systems] are in need of urgent review and possible reworking. There needs to be a simple system, for example when checking a single car for victims. To spray an entire USAR TF marking on each car is not practicable but the word CLEAR is not UN approved".

Another area of concern raised by respondents was the damage to property from the marking system, especially to structures that were not damaged but had to be searched. In response to this dilemma, some teams opted to not conform to the guideline and spray paint the footpath or the glass frontage. One respondent noted:

"We were on 23rd/24th/25th Feb directed to no mark any buildings, use only the foot path with a limited marking, not INSARAG format. Later markings still mixture of clear with team name, date. spray paint varied due to availability, one point the replacement paint was bike repair paint in browns, off yellows and greens which proved useless".

The issue of damage to property caused by spray paint was also highlighted in the National Commanders Inquiry Report (New Zealand Fire Service, 2011, p. 17). It is agreed the teams were following the guideline and that markings may be applied pursuant to section 92 of the Civil Defence Emergency Management Act 2002. Additional protection from liability is also found within the Fire Service Act 1975 (s.43) and Civil Defence Emergency Management Act 2002 (s.110) which were applicable to the urban search and rescue response in Christchurch.

Finally, some respondents made note that due to no markings being used or incorrect markings being applied, many structures were subsequently searched again unnecessarily, wasting time and placing personnel at risk.

Literature Review

Despite the significant costs associated with deploying international search and rescue teams, the literature is scarce of proving their effectiveness, with some arguing that the cost of deployment would save more lives if allocated pre-event in disaster risk reduction and mitigation programmes. Others retort that the saving of even one life can not have a tangible price placed upon it. Some would also suggest that the extension of international rescue teams is more of a political gesture than based on humanitarian needs alone, such as the deployment of the New Zealand Task Force to Japan following the devastating Tsunami in March, 2011, in which the mission saved no lives. The politics of international search and rescue can be seen at all levels. The General Assembly Resolution and INSARAG Guideline expect any internationally responding team is accredited at the Medium or Heavy classification. The New Zealand Task Force remains unaccredited to any level according to the INSARAG directory (INSARAG, 2011). It could be argued that it was hypocritical that the New

Zealand Government declined to accept unaccredited teams into Christchurch following the February 2011 earthquake (Field, 2011), yet deployed it's unaccredited team to Japan. Others may view this exchange as a practical means to demonstrate the government's genuine compassion and moral obligation to reciprocate.

In review of available post-mission reports on the Virtual OSOCC, it would appear only the Australian teams have uploaded these (OCHA, 2011), despite the requirements to provide such a report under the guideline. Though not focused specifically at urban search and rescue operations, the New Zealand Fire Service National Commander commissioned a internal inquiry did make some remarks concerning the application of search markings (New Zealand Fire Service, 2011, p. 17):

> *The United Nations Office for the Coordination of Humanitarian Affairs field support section International Search and Rescue Advisory Group (INSARAG), of which New Zealand is a member, has devised guidelines for building markings in order to ensure optimal coordination on a work site by USAR teams. These markings are not widely known by those NZFS personnel not in USAR. We were also advised that these markings were not always used consistently by international USAR teams during the search and rescue operation which caused further confusion.*
>
> *Another issue raised with us was that the spray painted markings on certain surfaces and motor vehicles had resulted in considerable rectification expense. While we can understand the concern expressed we note that USAR crews followed the INSARAG guidelines.*

These comments are of interest. Firstly, the New Zealand Fire Service is the Lead Agency for USAR in New Zealand pursuant to the National Civil Defence Emergency Management Plan. Changes in the USAR organisation from 2005, has lead to a deterioration of relationship between New Zealand USAR Task Forces and New Zealand Response Teams, more so at the strategic level (personal observation). Some senior officials within the New Zealand Fire Service have argued there is no need for (volunteer) light rescue teams as their service was to train all of its members to and beyond USAR Category 1 Awareness (personal observation). Despite such intentions, no such capability has been developed significantly beyond the three task forces, a point well proved by the National Commander's report admitting the lack of awareness by their operational staff of a marking system which is seen by both domestic and international USAR practitioners as important (98.3%, n=57, indicated search marking compliance was moderately to extremely important). The report also purports that international USAR teams inconsistently applied search markings (causing confusion), yet the SMAS and survey results suggest the exact opposite. New Zealand Task Force (NZ Fire Service) teams actually scored the lowest in applying the INSARAG marking systems correctly.

Discussion and Implications

General

The INSARAG marking system proved to be a useful tool in the aftermath of the Christchurch earthquake. Although there was variation across the team types and country of origin, the system worked reasonably well when applied correctly. The INSARAG marking system appeared to be favoured over the FEMA marking system as it allowed for more information to be illustrated and is less codified. There did however seem to be a general theme that many teams were not aware of the revised structural marking and the removal of the victim markings from the guideline. Almost unanimously (98.2%), surveyed respondents indicated that it was important that USAR search markings be applied correctly in accordance with the INSARAG standard. The standardisation and consequential correct interpretation of search makings should lead to a more effective rescue response through minimising duplication of search efforts, safer working environment for rescuers, improved detection and retrieval rates of victims, improving international interoperability across rescue teams, which all lead for better outcomes for the affected community.

Application performance

There was a slight increase in adherence scores in the days following and this is likely to be attributed to verbal pollination of the guideline's understanding between team members. New Zealand Response Teams scored the highest in their application of search markings, even above the average of internationally accredited INSARAG teams. This is likely to be contributed to by their culture of regular USAR specific training as volunteers (albeit at a light level) and an autonomous interest to follow changes of the guideline regardless of the lack of information or updates from the country's focal points. International teams were second in their adherence scoring, reflective of the need to ensure all operational members are familiar with the guideline as part of their accreditation. The New Zealand Task Forces scored the lowest which may be caused by a lack of regular ongoing training and exercising in comparison to the other team types and lack of information or updates from the country's focal point (such as changes to the guideline).

Key recommendations

Structural Markings

The guideline for the structural marking should be revised as follows:

1. Clarify that the size and colour of the marking is only a recommendation.
2. Recommend that a universal date format being adopted (i.e. 22 FEB 2011).
3. That only one time (entry or exit) is listed to decrease paint consumption.
4. Placement of the marking ideally should be on the front of the structure; however other options including on the structure's footpath or fence may be less preferred alternatives, noting that liquefaction and traffic may affect the survivability of footpath placed markings.

5. That the structural assessment (Go or No Go) should be abbreviated (to G or N) to decrease paint consumption and reduce encouragement of public to re-enter buildings safe for rescuers, but not safe for public.
6. Consider standardised international team naming conventions to allow for country and level to be included. For example NZ1M (New Zealand Team 1 – Medium), US2H (USA Team 2 – Heavy), FJ3F (Fiji Team 3 First Responder). This would allow the "completed to team capacity" circle marking to be better understood in context to the team's level of capability (First Responder, Light, Medium and Heavy).
7. That null values (such as victim data) not be used to decrease paint consumption
8. The horizontal line is the indication of clear and once applied the structure should not be re-entered by rescue personnel.

Training and Competency

9. The guideline and in-country training guidelines for urban search and rescue should mandate periodic search marking competency tests for rescue personnel.

Information Sharing

10. The guideline should include Terms of Reference (TOR) and for INSARAG country focal points (political and operational) and develop a mechanism to ensure guideline updates and other relevant information resources and opportunities are promulgated to all stakeholders (accredited and non-accredited actors).

Rapid Clearance Mark (RCM)

11. The guideline needs to include a simple marking able to be used by non-USAR first responder to mark buildings as clear. This could also be used by USAR practitioners to note that non-structural search areas (vehicles, caravans, boats, small sheds, collapsed walls etc) have been cleared. To distinguish this from property owners or occupiers, a circle with a horizontal line could be used (i.e. ϴ) as suggested by one respondent. The marking of "clear" could be left as a common sense application for use by property owners and lay-persons.

Low Damage Search Marking (LDSM)

In particular when searching suburbs with minimal damage, consideration should be given to an alternative means to mark the structure other than spray paint. Several options have been put forward by the sample group including coloured card and waterproof paper, stapled to the fence with the search assessment marking applied using a permanent marker. Such a placard based system (figure 14) has already been used, including following the Bastrop Fire (E. Macaluso, personal communication).

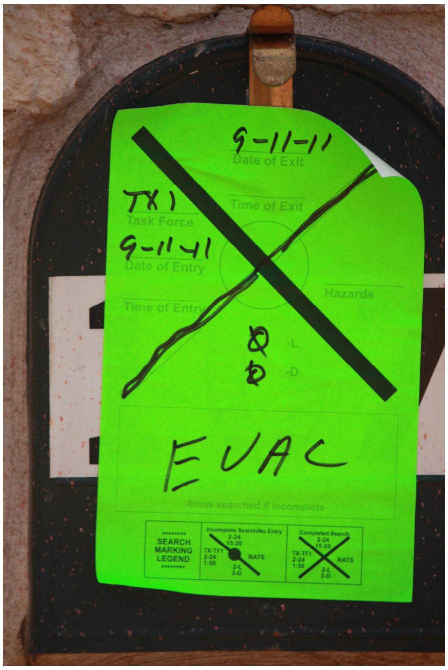

Figure 14: FEMA search assessment marking in use by Texas Task Force 1, Bastrop Fire, 2011.

Some countries have developed post-response building evaluation systems that include the use of coloured card (New Zealand Society for Earthquake Engineering, 2009). However, the use of coloured card as a search marking may be problematic given potential conflict with such engineering assessment placards systems.

12. The INSARAG guideline should suggest the use of waterproof paper (A4 or Letter size) being affixed to the structure or fence seems with the structural marking information being written on in permanent marker. The structure's address should also be placed on the header in case the marking sheet separates from the structure.

These sheets could be pre-printed with base information (i.e. box and team identification, as per Figure 14) to expedite search operations. One respondent indicated a potential problem of using a smaller card option, that being it would be difficult to read whilst driving in comparison to the traditional one metre square spray painted box. However should a building be collapsed or damaged, the standard (spray painted) structural marking should be used instead making the property easy to identify.

Victim Markings

There was a lack of data pertaining to victim markings which were used following the Christchurch earthquake, despite the victim marking system being removed from the INSARAG Guideline. The victim marking system has been revised and included in the current FEMA USAR Task Force Field Operations Guide (Federal Emergency Management Agency, 2003a).

13. The INSARAG guideline should include the revised victim markings or at least provide commentary and reference resources in which personnel can refer to in order to decode such markings if deployed to countries which domestically use these.

Conclusion

The evolution of the INSARAG guidelines appears to give good effect to standardise operational methodology including search marking systems within the international community. It will always be important that end user practitioners are involved in the review of such systems and more importantly, the changes being promulgated effectively. The evaluation of search marking adherence to the INSARAG guideline in this article is not necessarily a reflection of the actual effectiveness of search and rescue operations following the 22 February 2011 Christchurch earthquake. Further consideration is needed around the interpretation, application and adjustment of the INSARAG structural assessment marking by the international working groups responsible. Some team types need to spend more attention to ensuring basic markings are understood and applied in accordance with current guidelines to ensure an improved level of response in the future. Further research is needed and should focus on the effectives of international search and rescue programmes (in particular their benefit in comparison to local capacity building and risk reduction programmes), effectiveness of victim markings and changes to the markings (such as LDSM and RCM suggestions).

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About the author

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Abbreviations

CDEM	Civil Defence Emergency Management
FEMA	Federal Emergency Management Agency (US)
FOG	Field Operations Guide
ICP	Incident Control Point (aka Incident Command Post)
IEC	INSARAG External Classification
INSARAG	International Search and Rescue Advisory Group
LDSM	Low Damage Structural Marking
MCDEM	Ministry of Civil Defence & Emergency Management
NDMO	National Disaster Management Office
OCHA	Office for the Coordination of Humanitarian Affairs
OSOCC	On Site Operations Coordination Centre
NZ	New Zealand
NZFS	New Zealand Fire Service
NZRT	New Zealand Response Team (Registered)
NZTF	New Zealand Task Force (part of New Zealand Fire Service)
RCM	Rapid Clearance Marking
SHE	Structural/Hazard Elevation
SAM	Search Assessment Marking (FEMA)
SMAS	Search Marking Adherence Score (Glassey, 2011)

TOR	Terms of Reference
UN	United Nations
UNDAC	United Nations Disaster Assessment Coordination
USAR	Urban Search and Rescue

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