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The Journal of Search and Rescue (JSAR) is an open access peer-reviewed electronic journal for the collation and distribution of original scholarly material on search and rescue (SAR).

It is being supported by the in-kind work and contributions of the Editorial Board. There is still the need for a dedicated journal serving those with a direct interest in all disciplines of search and rescue including: rope rescue, water (flat, swift and marine), ice rescue, wilderness search and rescue, structural collapse rescue, trench collapse rescue, cave rescue, dive rescue, motor vehicle extrication, canine search, technical animal rescue, air rescue, search theory, search management, and mines rescue. JSAR exists to fulfil that need.

Article submissions from these and other SAR disciplines are welcome. Launching this journal on the internet offers a relatively cost-effective means of sharing this invaluable content. It affords the prompt publication of articles and the dissemination of information to those with an interest in SAR.

JSAR will provide a forum for the publication of original research, reviews and commentaries which will consolidate and expand the theoretical and professional basis of the area. The Journal is interested in theoretical, strategic, tactical, operational and technical matters.

Advertising within JSAR will be considered in the future to ensure sustainable funding is available to enhance and continue the work of the journal. The publication of an article in the Journal of Search and Rescue does not necessarily imply that JSAR or its Editorial Board accepts or endorses the views or opinions expressed in it.

Cover Image: USAR technicians prepare a flying raker.

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Editorial

Welcome to Issue 1 of the 5th Volume of the Journal of Search and Rescue. This issue is shorter than normal, due in some ways to the nature of the Journal, with an entirely voluntary staff, all of whom work in the emergency services and so have to find time to review and edit amongst their other numerous duties. It is also due to the circumstances we find ourselves in as SAR responders wherever we are. As the global pandemic moves through its phases, our colleagues have found themselves called upon more than ever to use their expertise to aid those in need. The world of SAR continues apace, and beyond the pandemic this month we have seen devastating floods across Europe, Wildfires in North America and in Africa, as well as an earthquake in the Pacific. It seems clear to me that the challenges facing the world mean that our skills, knowledge and expertise has never been more needed. The good news is that we have a number of papers in review already, which should mean that Issue 2 is hot on the heels of this issue, meaning we can release two issues for 2021, as normal.

This issue contains work concerning object recognition and detection, which is of course the bread and butter of SAR: the ability to recognise specific objects in space is fundamental to all of the subsequent operations that might be needed to save a life. The second article is a non-peer-reviewed technical work, that proposes a multihazard risk assessment tool for swiftwater and flood rescue. Finally, we have a book review considering a recent work on voluntary mountain and wilderness rescue.

We have received some positive feedback from the sector during the creation of this issue, from law enforcement and humanitarian agencies across the world. I mention this not merely as an idle brag, but for two reasons. The first is that to my knowledge this is the first unsolicited communication from the sector complementing the Journal on its work for no reason other than it has had a positive impact. The second speaks to my earlier points at the beginning of this editorial, and I believe it demonstrates the impact of our work as a community as a whole and the importance of that work.

There is an increasing momentum towards professionalism and accreditation at an international level with at least three professional institutions providing training accreditation, support, and networking. I have been greatly impressed with the way that these organisations have presented themselves and the positive impact they have had on training, research, and operations in the short time they have been in existence. This has meant that, despite the workload and pressures of work, family, research, and the journal competing this last six months has been an enjoyable one. That said, it is time for a break and so I'll be taking a year's sabbatical after this issue and handing the reins over to Dr Koester and Dr Hammond until the Summer of 2022. I definitely have a backlog of research to catch up with, so maybe I will be able to submit a paper to the journal myself and see the workings of the Journal from the other side.

Enjoy this Issue, keep saving lives and contributing to your communities, keep researching and most importantly keep safe.

Dr Ian Greatbatch

London

Object recognition and detection: Potential implications from vision science for wilderness searching

Stephen McClanahan PhD WEMT
From Search and Rescue Ohio and Mountaineer Area Rescue Group, USA
Appalachian Search and Rescue Conference
Email mcclanahan.sf@gmail.com

Abstract

Field searching relies heavily on human vision and the ability to recognize objects that are out of place in their environment. Searchers seek to continually improve their ability to detect clues. This paper provides an overview of findings from vision science investigations as they relate to the ability to detect and recognize objects. Vision research provides a solid basis for the utilization of the searcher's cube and the walk/stop/search cadence. It provides insights into the psychological factors that inhibit detection of low prevalence clues and means to reduce these barriers. Lastly, investigations from vision science illustrate the key elements needed in training to improve visual search outcomes.

KEY WORDS: *wilderness search and rescue, vision, visual search, foveal field, low prevalence effect*

Introduction

During a search and rescue operation, the goal of both searcher managers and searchers themselves is to rapidly and efficiently bring the search for a lost or missing person to a successful conclusion. Modern search theory is built upon the science of probabilities; in order to maximize the probability of success (POS), it is necessary to individually maximize the probability of area (POA, the probability a lost person or physical clue is in an area being searched) and the probability of detection (POD, the probability of detecting the lost person or clue, assuming these are in the area being searched) as the former is simply the product of the latter two. In the past several years, there have been significant steps forward in addressing the parameters that influence POD. It is known that POD is related to several search variables that can either be controlled during a search or estimated for a specific terrain in which the search is being conducted. These dependencies are best described by their mathematical relationships. Most approaches to search theory use the random search relationship originally developed by Koopman (1946, 1980), specifically:

$$POD = 1 – e^{-coverage}$$

where coverage is defined as the ratio of the area effectively swept (A_s) to the total area assigned to be searched (A_a). In turn, area effectively swept (A_s) is the product of the effective sweep width (W) and searcher effort (the latter being defined as the distance a searcher covers x the average rate of travel x the number of searcher hours involved in the task).

$$Coverage = A_s/A_a = [Effort \times W] \div A_a$$

Thus, in a hypothetical situation where all variables are constant except effective sweep width, the probability of detection would vary with the effective sweep width in an exponential manner.

$$POD = 1 - e^{-KW}$$

where the constant K encompasses all other variables.

The effective sweep width, W, is a statistical parameter; it is derived from the notion that a searcher is passing through an area with a large number of identical stationary objects that are uniformly distributed throughout the area. W has units of length and is a measure of the effectiveness with which a particular sensor can detect a specific object under specific environmental conditions (Koopman 1946). Within the context of this paper, the sensor is a human searcher. As the searcher passes, some objects will be detected, and others missed. The effective sweep width is statistically defined as the search width at which the number of missed detections inside W equal the number of detections outside W, as shown in Figure 1.

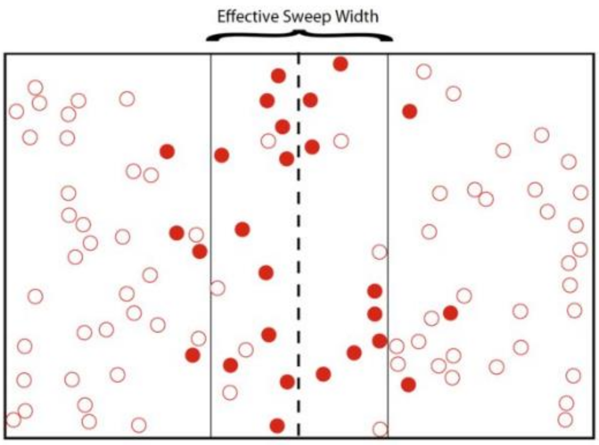

Figure 1: Effective Sweep Width (Banning 2017)

A solid dot indicates a detected object; an open circle indicates a missed detection.

Larger effective sweep widths are associated with situations where detection is greater. Effective sweep is statistically robust. As stated by Frost (1999) and shown by Koester (2014) and Chiacchia and Houlahan (2010), effective sweep width depends on the terrain environment, seasonality and search object characteristics as well as the searcher. In the context of wilderness search and rescue where a human is visually searching for the missing subject as well as physical clues, object detection and recognition by a searcher intuitively underpins effective sweep width and thus the probability of detection. Thus, improving this skill in a significant fashion would be expected to directly lead to more successful search operations, assuming all other parameters constant.

Vision science literature may reasonably be expected to provide insights regarding how significant improvements in searcher performance may be achieved. In this discipline, visual search is defined as the process of locating a target among a set of distractors in a scene, distractors being all other objects in the scene that resemble but are not the target. (Wolfe 1998). Visual science attracts great interest in its own right, but the ability to better recognize objects in the field of view has real-world consequences across a number of distinct disciplines. Whether it is improved luggage screening at airports for guns, bombs or other weapons, enhanced medical interpretation of diagnostic images so fewer cancerous tumors are missed, increased ability to inspect crowds for possible terrorists, patrolling a border, lifeguarding a pool or a variety of other endeavors that involve visual inspection, understanding how objects are viewed by human observers and recognized is critical as it allows for the possibility of improvement of the skill.

This paper provides an overview summary of the rich and emerging literature from vision science investigations that are of relevance to individuals involved in wilderness search and rescue, most of whom are not intimately familiar with this area of scientific research. The goal is to provide an understanding how objects are visually detected and recognized. (It is understood that, in the context of wilderness searching, objects of interest include not only the subject but articles of clothing, footprints, or other visible signs.) As such, this paper briefly reviews central vision, eye anatomy and eye movements involved in object recognition as well as the cognitive drivers that provide for interpretation of mental images of objects. Psychological factors that significantly influence the ability to recognize objects are also reviewed. Patterns of visual search from professional searchers are compared to novices and the impacts of training on real world search performance are discussed. As will be shown, vision science has much to teach regarding how to better perform searches in the wilderness; several areas are suggested for potential improvements.

Central foveal and peripheral vision

As light passes through the cornea, it is focus by the lens onto the retina at the back of the eye where the two types of photoreceptor cells reside (rods, cones, so named for their anatomical features). Rods greatly outnumber cones, approximately 91 million per retina to 4.5 million per retina (Purves 2001). Rods are extremely light sensitive and are responsible for recognizing movement and peripheral vision, among others. Rods are symmetrically distributed around the retina, except for the fovea, a small 1.2 mm diameter, central dimple in the retina located directly behind the lens. Not only are the photoreceptor cones responsible for color vision located within the fovea (with significantly fewer in the surrounding periphery), but light impinging upon the fovea is critical to our ability to recognize objects.

Human vision is an active process; visual information is received during brief periods of stable eye positions (fixations) before the eyes subconsciously move (termed saccades) to focus on another area (Ludwig 2014). Central vision or the foveal field of vision as it is sometimes referred to, is only a few degrees (less than 5°) wide. Carrasco and co-workers (1995) studied the effect of moving the target off center from the fovea (termed an eccentricity effect) by having subjects respond when they identify a specified target in a visual field presented to them. Their work clearly showed that both the time it takes to detect the target and respond, and the detection error rate increase with increasing eccentricity angle;

just a few degrees off center and these effects manifest. These results have been replicated by others (for example, Wolfe 1998, Scialfa 1998).

Wolfe and colleagues (1998) presented experimental evidence that items located near the fixation point receive more mental attention than those in the periphery and that this is a primary driver of the eccentricity effect; said differently, light focused on the fovea receives preferential cognitive processing and provides the sharpest, clearest images to the mind such that objects are most easily recognized when brought into the central or foveal field of vision (Eckstein, 2011). In addition, there is a general decrease in attention given to objects with increasing eccentricity (Staugaard et al 2016). Light impinging the retina at places other than the fovea is not nearly as efficient for object detection and recognition, Visual acuity is reduced 75% for objects just 6 degrees off center from line of sight (Purves et al 2001). Any part of an image that falls outside of the fovea may not be recognized because fine, spatial detail and form recognition occur within the foveal field (for example, Eckstein 2017, Strasburger 1996). Foveal analysis serves to identify the currently fixated object (Ludwid, 2014). Moreover, dependence on foveal vision for object recognition seems to be innate; in studies with subjects who had 10-20 years of lost central vision due to disease (Stargradt disease), no evidence was found of increased ability to use peripheral vision in this capacity (Boucart 2010). In studies of individuals with ophthalmoplegia (paralysis of the eye muscles such that normal eye movements are not possible), saccade-like head movements are made to visually sample the environment via the fovea (Gilchrist 1997).

Peripheral vision is involved in the detection of movement as well as night vision. In addition, peripheral vision does play an active role in visual sampling of the environment by regulating decisions regarding where to fixate next. Research indicates that saccadic eye movements are guided by peripheral vision up to 80-100 msec prior to eye movement (Caspi 2004, Ludwig 2007, Becker 1979, Ludwig 2014) Interestingly, studies have indicated that the cognitive processes involved in foveal analysis and peripheral selection can proceed simultaneously by parallel mental processes. (Ludwig 2014).

Eye Movements and Points of Fixation

Visual searching involves both eye movements and associated attention processes (Van Der Lans 2008). Eyes have a quick and continual motion, known as saccadic movement, that is used to focus on various points and create a mental picture of an image from a given scene. Saccades are extremely fast; the eye can focus on a target within fractions of a second. Measurements indicate between three and five saccadic movements each second (Henderson 2003, Zelinsky 2008). When observing a stationary image, eyes focus on an interesting point before rapidly moving to the next. Each of these points of focus is referred to as a fixation point (Ludwig 2014). Eye movements can be tracked by various means. Figure 2 shows the 1-minute gaze pattern of an air-to-ground searcher as an example of the saccadic movements, measured by eye tracking (Croft 2007).

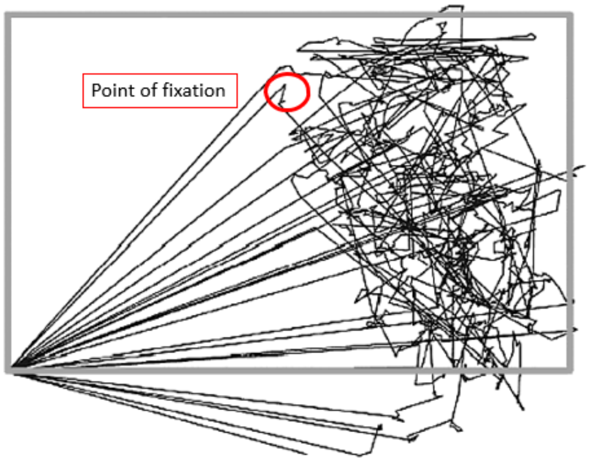

Figure 2: Example gaze pattern (modified from Croft 2007)

As stated above, accurate vision sufficient to recognize objects is largely limited to the fovea. To identify objects that are observed peripherally, the eyes bring it into the foveal field of vision by a saccadic movement (Poth 2015). Furthermore, mental processing of visual information is limited to sensory input gathered during fixations; no information is acquired during the saccadic movement (Martin 1974, Campbell 1978) that would otherwise result in a blurring of the image. Stated differently, pattern information is only acquired during periods of stability (Henderson 2003).

Precisely how the brain subconsciously decides where to point the eyes during a visual search is not completely understood and remains an active area of research (for example, Eckstein 2011, Fluharty 2016). Evidence suggests at least three factors are involved: low-level salient features (regions in a scene that differ locally in some fashion such as color, orientation, etc.), scene context (the relationship of the object to the search scene, e.g., room ceilings are not searched when looking for missing car keys) and target template information (i.e., visual information is compared to mental images of targets to determine if a viewed object is the target of the search) (Malcolm 2010). As a result of the latter, objects that share some characteristics with the target but in fact, are not the target (termed distractors) are more likely to be fixated upon than others (Zelinsky 2008).

It is tempting to inquire about the role of fixations in object recognition, such as the number of fixations needed, their duration, etc.; such factors depend on the complexity of the scene and object. For example, in much of basic vision research, response times (time needed to identify the target or conclude it is absent) are measured; response time is essentially the number of fixations multiplied by the fixation duration (Zelinsky 1995). In studies where the target letter 'Q' must be identified in a field of 'O' distractors, response times are short, and few fixations are needed (Zelinsky 1995). The number of fixations required to locate targets increases as the complexity of the scene increases, forcing the searcher to a serial mental processing mode which slows down the visual search. In addition, there is evidence that searchers spend significantly longer on their initial saccade than subsequent ones

(Zelinsky 1995). In real world visual searches of mammograms, experienced radiologists utilized an average of 30 fixations per image for their diagnosis (Nodine 2001).

Eye movements clearly reflect the attention of the searcher. As stated by Zelinsky (2008), “manual search measures correlate highly with the number (and distribution) of gaze fixations occurring during search”. In studies of everyday activities such as making tea, Land (1999) found that foveal vision was always focused on the object being manipulated, with few fixations unrelated to the task. Fixations preceded the initiation of manipulations by about 0.5 sec and then moved to the next object about 0.6 sec before completion of the current manipulation, the eye thus closely following every step of the process. In a study of walking over an irregular surface, Patla (2003) observed that over 50% of subjects’ gaze patterns were focused on the path of travel. When they did focus on the landing target, they did so approximately 1 sec prior to contact. In a study of walking over a surface that demanded precise footfall, subjects’ eye fixations are essentially completely on the task at hand (Hollands 2001). Galna (2012) measured a 4-fold increase in the frequency of saccadic eye movements when subjects were tasked with walking while approaching a simple turn as compared to walking straight. Foulsham (2015) has summarized several investigations such as these which clearly demonstrate eye involvement in everyday activities, whether intentional or not.

Eye movements also reflect the absence of attention by the searcher. During periods of mind wandering (task-irrelevant internal thoughts), Krasich (2018) measured fewer and longer fixations as compared to periods of attentive scene viewing.

A fuller discussion of the interplay of saccadic eye movements and fixation points is beyond the scope of this paper; the search and rescue reader is referred to the review by Mardell (2013).

Cognitive Processes involved in Vision

Studies in the basic visual search sciences have delved deep into the mental processes involved. A review of those is well beyond the scope of this paper; the reader is referred to a review by Eckstein (2011). There are, however, a few aspects that are of direct relevance to wilderness search and rescue.

The scene itself provides context that guides searches (Wolfe 2011). Search often involves utilizing prior knowledge (referred to covert attention) regarding the relationship of an object with the scene in which it exists to guide the visual examination for that object; such knowledge can greatly improve search success (Eckstein 2017). Thus, tabletops are searched for one’s coffee cup but walls are not. With regards to wilderness SAR, evidence of the physical passage of someone (sign) is searched for on or near the ground.

Vision science has focused on the cognitive processes that guide eye movements; this research indicates two different broad governing mechanisms, so called two modes of attention (Katsuki 2014). In the top-down mode, eye movements are directed according to the goals and desires of the observer.

The top-down attention mode is a voluntary, wilful process. It involves internally selecting a specific location or feature or object upon which to search. This mode is used when searching for specific objects. The bottom-up mode drives eye movements in response to the visual properties of the target. Characteristics of search objects that impact detection and recognition include size, color, shape, angles, lines, orientation and contrast with the background or environment as well as the degree of movement. These characteristics are deeply involved in searches where the background is complex and heterogenous; a potential target must first be separated from the background before recognition can be achieved and segmentation is driven by these object characteristics (Wolfe 2002).

Both mechanisms are in constant use, interact with each other, and involve multiple distinct areas of the brain. In both, visual images of objects are compared to mental representations to determine recognition of the object. Importantly, the research indicates that the top-down mode can be intentionally influenced to improve search success. That is, the observer's mental picture of the target is one of the most important factors in object recognition and this mental picture can be improved upon, often with dramatic improvement in detection performance (Eckstein 2011). Even partial views of objects may still lead to target recognition. When presented with incomplete information, the visual system fills in the blanks (Gold 2000, Chong 2016).

Vision research has shown that there are important psychological influences on object recognition that are of relevance to wilderness searching. These experiments often involve presenting many images to participants where the number of images that contain the target as well as the number of distracting elements in the image can be easily varied. A variety of parameters are measured including the rate of missing the target, the manner in which the eyes fixate on the image and the time participants take to determine if the target is present or absent. From multiple experiments such as these, a psychological influence termed the low prevalence effect has been identified and studied. The <u>rate</u> of missing targets increases substantially when the frequency of images containing the target drops (Wolfe 2007, Rich 2008.); stated succinctly, rare targets are disproportionally missed.

For example, a series of images were shown to participants where, on average, every other image contained the target; under these conditions, participants missed the target at a rate of approximately 10% regardless of whether the target object is embedded in a set of 6 or 12 distractors. Identical experiments conducted, where the prevalence of the target is lowered to 2%, reveal the miss rate rises dramatically to approximately 40%. Research by Wolfe (2007) have explored the nature of the low prevalence effect and have shown it to be robust. The low prevalence effect is characterized by two distinct elements: the first is a marked elevation in the rate of missing targets and the second is a decrease in the participant’s reaction time in determining if the target was present or absent. Experimental evidence reveals this effect is caused by a mental shift on the part of the searcher; when searching under low prevalence conditions, there is a subconscious expectation is that the target is most likely not present. Some research has indicated this effect is due to failures of perception to recognize the target (Hout 2015). A more widely held perspective comes from work by Wolfe and Van

Wert (2010) who have developed evidence that the low prevalence effect reflects a shift in the decision criterion (as to whether a target is present or absent) to one of becoming more conservative; rare targets are judged more likely absent even when present. It reflects an implicit bias.

Wolfe and his co-workers (2007) have published a variety of experiments designed to explore this psychological phenomenon in greater detail. Several experiments were conducted where participants searched for targets in images that mimicked airport screening of luggage. After some initial practice images, participants were then tested for their ability to detect targets. When challenged with low prevalence targets, participants were able to improve their performance when searching was regularly interrupted and participants shown several images where the target was present at high prevalence rates. By providing bursts of training at high prevalence, participants' missed error rate was cut nearly in half, from approximately 45% to 20-25%. The false positive rate also increased. Additional experiments have revealed that low prevalence targets are in fact fixated upon but are missed due to the perceptual failure of the participant to identify the target (Goodwin 2015, Hout 2015). The mental expectation of not finding the target creates the bias that results in not recognizing the target when, in fact, it is present. Yet, as pointed out by Eckstein (2011), enhancing the observer's mental image of the target improved performance.

There may well be evidence of a similar effect in wilderness search and rescue. Koester and co-workers (2014) measured the relationship between effective width and range of detection using three different kinds of search objects: high, medium, and low visibility objects. Effective sweep width and range of detection were highly correlated, but the correlation depended upon the visibility of the search object. For high visibility objects, a correlation of 1.8 was measured. For medium visibility objects, the correlation coefficient was 1.6 and for low visibility objects the correlation was 1.1. The authors noted that the smaller correlation for low visibility objects was not simply due of the difficulty of seeing the objects against the background environment; that effect had already been accounted for in the lower range of detection for those objects. The smaller correlation stemmed from the fact that, psychologically, these objects are less likely to be noticed by the searcher apart from their lower visibility. A similar effect can be shown in independent data from Koester and coworkers (2004) when correlations between effective sweep width (W) and range of detection (specifically AMDR, Average Maximum Detection Range) are calculated; 1.7 for high visibility objects, 1.5 for medium visibility objects and 1.2 for low visibility objects. Such observations lead to the question of whether searching for a low visibility object is psychologically similar to searching for a rare target. That is, because it is difficult to detect, is there a similar subconscious expectation that a low visibility target is most likely not present? In wilderness search and rescue, search objects and clues are often both low in number and difficult to see against the environment, making the psychological influence of substantial importance.

Implications for Search and Rescue

Foveal vision:

Collectively the research summarized above provides valuable insights applicable to wilderness search and rescue. To begin, recognition of the importance of the foveal field of vision is critical. The Civil Air Patrol attempts to incorporate this concept during their training of air-to-ground spotters (Civil Air Patrol, 2017). In their application, visual scanning is the process of investigating or checking an area by training scanners to use a systematic eye movement pattern. Employing their outstretched fist as a visual guide, the spotter attempts to bring a search area of approximately 10 degrees into the foveal field of view, focusing on this area for a few seconds before systematically moving to the next overlapping area. Using this process, a trained spotter can systematically cover an area as the search plane is moving.

It is fair to ask whether such a visual scanning approach provides for demonstrably better search results. Croft (2007) conducted a real-world test where spotters were tasked with identifying known targets as they were flying overhead. Targets, sheets of plastic mimicking a Cessna 180 wing, were planted in the search field. Ten spotters with an average of 5 years-experience each participated in this experiment. Data extracted included the points of fixation, the visual coverage, the distance between fixation points, the visual scan pattern utilized as well as the frequency of finding and identifying the target. Despite training, the vertical scan technique was used only approximately 40% of the time. Visual coverage of the area was low at approximately 25%, assuming a 5 degrees circle around each point of fixation. Search success rates were approximately 30%. Importantly, this research demonstrated that search success was dependent upon 3 factors: the number of fixation points (the more, the better), the Inter-fixation distance and its variability (small and consistent is better). These results indicate that the scanning technique has merit, but it is difficult for searchers to learn and consistently apply this method, particularly while moving at relatively high speed in an aircraft.

To the extent that the wilderness environment demands a searcher to focus on their path as they move through their assigned area, it is important that they stop in order to utilize foveal vision critical for the detection of search objects. Research clearly shows that when moving, eyes are largely fixated on the path, where the next step will fall and hence, not the target (Patla 2003, Galna 2012). In addition, complex 3-D scenes of the wilderness can effectively shield objects from one specific viewpoint, thus requiring multiple views to overcome.

Many within the wilderness search and rescue community are taught the concept of the searcher cube, a hypothetical 6-sided cube whose center is located with the searcher and whose facial dimensions are equivalent to the effective sweep width (Stoffel 2013). The utility of the searcher cube is that it helps define the length a searcher can travel before stopping and, using foveal vision, inspect the surrounding scene via all 6-faces. For the searcher to fully utilize his/her foveal vision in pursuit of the target object, it is critical to stop. In addition, it seems intuitive that searchers should refrain from idle conversation and work to maintain their attention on the search task since eye movements clearly reflect the attention of the searcher. While the concept of using central vision is not foreign to search and rescue (for example Civil Air Patrol, 2017, Stoffel 2013, Illinois Search and Rescue Council, Ontario Search and

Rescue), it is not apparent that it is as widely factored into training as indicated when search tasks require greater thoroughness.

Low Prevalence Effect, Distractors, and other complications

Wilderness searching represents a situation where target prevalence is low and searchers spend most of their time examining terrain that does not contain a target (i.e., clue). Target characteristic such as small size, low contrast with background, low visibility, noncanonical orientations, etc. make detection difficult (Schuster 2013). Target identity is often not known. Search scenes are complex and variable. Environmental conditions are frequently unfavorable to searching. Because of these factors, it is likely searchers are psychologically influenced to some degree into believing, that in any given scene, a target is most likely absent and hence, be quick to conclude no targets (clues) are present. There is no a priori reason for wilderness searchers to be immune from the low prevalence effect; there are, however, some obvious steps that can be taken to offset its impact.

As stated by Eckstein (2011), searchers knowledge of the physical characteristics of a target is one of the most important factors for efficient and improved search. Thus, in the context of wilderness search, enhancing mental images of targets in the minds of searchers is important. It has been suggested that it is possible to increase the probability of detecting clues by showing surrogates of expected clues to searchers during their task briefings (Stoffel 2013), provided these are known from SAR interviews, witness reports, etc. Target uncertainty can be reduced by showing a preview picture of the target; actual pictures reduce the time to find a target more than word clues (Wolfe 2004). Rather than just a verbal or written description of search objects, a physical surrogate should be shown. Research indicates even passive exposure to a stimulus can affect performance (Schuster 2013). Searchers should be allowed to view these objects as they may appear in the environment, lying on the ground in differing orientations. In addition, the individuals performing the briefing can enhance psychological ability of searchers by avoiding such terms as “low probability areas” as these likely create a negative psychological bias. Some search teams have already incorporated these elements into their training; the research summarized here indicates this training should be more widely utilized.

Expert Searchers

Table 1 lists studies that have examined professional expert searchers or compared them to either trainees or novices to learn what differential factors are at play. Inspection of the data in Table 1 reveals that experts are far from perfect; within expert ranks, the performance of some is much greater than others (Schwaninger 2003b). And experts still miss targets such that algorithms that redirect their search improve outcomes (Nodine 1990). Nonetheless, when compared to novices or trainees, experts tend to dwell longer than others (i.e., are slower) while inspecting a scene before reaching a conclusion regarding target present or absent; in addition, their eyes fixated more on targets. Their search technique is more consistent and more accurate. From a study of expert radiologists, Drew (2013) concluded that it was probable their expertise consisted of both hardwired guidance by basic features of targets (color, etc.) as well as learned guidance from their practice. The studies listed in Table 1 span both airport security and radiology; both involve examination of images on a computer screen. Yet the outcomes of these studies are in alignment with predictions of vision science and hence, there is no reason not to expect similar effects in wilderness searchers.

Training

Several studies in the literature have examined the role of training with respect to visual search in real world applications. Some of these are listed in Table 2. (Multiple other studies investigating the effects of various training regimens have focused on a basic understanding of the cognitive processes involved; these are not listed here.) From these investigations, a number of relevant insights can be drawn: 1) training almost always involves multiple short sessions conducted over an extended period of time, 2) training works; improvements in search performance are observed. It is also possible to improve vision itself, 3) a diverse, heterogeneous set of target objects is best to train with, and 4) improvements in vision training is transferrable to novel objects. All these elements are important to wilderness searching.

Conclusion

Vision science provides a solid foundation for understanding key factors of visual search, including foveal field of view and the role of saccadic eye movements. These lower level elements, along with the recognition of both bottom-up and top-down modes of attention involved in object recognition, set the groundwork for insights into improving visual search. Higher level cognitive processes involved in searching for low prevalent objects must be understood and managed, both in training as well as in search briefings. Lastly, the characteristics of training that have been successful in improving visual search should be incorporated into ongoing SAR training programs.

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About the author

Stephen McClanahan is involved in search and rescue in the Ohio, Kentucky and West Virginia regions of the US. He is a retired chemist.

Abbreviations

SAR: Search and rescue
POS: probability of success
POD: probability of detection
POA: probability of area (same as probability of containment, POC)
W: Effective Sweep Width
AMDR: Average Maximum Detection Range

Table 1: Impacts of Experience on Real World Search Tasks

Visual task targeted	Group receiving training	Test of Performance	Outcomes	Comments	Citation
Airport baggage screening	93 university students and 206 TSA officers	Search task: differentiate single 'T' target from multiple 'L' distractors. Groups compared across set of 256 images (target present at 50% prevalence).	Experienced TSA officers more accurate but slower (response times longer) to both locate a target and to conclude target absent.	Professional searchers more accurate but slower, suggesting they are performing the search task more diligently (Biggs 2013)	Biggs 2013
Airport baggage screening	72 TSA screeners and 103 university students	Search task: differentiate single 'T' target from multiple 'non-T' distractors. Groups compared across set of 255 images of varying target salience and prevalence.	Minimal difference in accuracy between professional and non-professional searchers. Professionals slower to respond (response times longer)	More consistent searchers (in terms of amount of time/trial) were more accurate.	Biggs 2014
Airport baggage screeners	80 airport security screeners	Screeners tested for ability to recognize threat items in different orientations, or superimposed by other objects or complex backgrounds	Objects in uncommon orientations or partially hidden or in complex environments more difficult to identify.	Significant differences exist between screeners, with some substantially better than others. Possible to test ability of screeners and identify need for training.	Schwaninger 2003b
Radiological examinations of chest CT scans	3 highly experienced radiologists	Eye movements tracked during examinations of 120 chest x-ray images, each viewed twice. Second reading had highlighted regions of either high dwell time or random location.	Re-examining areas of initial high dwell times that were initially not judged as lesions results in greater finds.	An algorithm that redirects a radiologist to re-examine areas originally dwelled upon but not judged positive effectively doubles the probability of converting a false negative to a true positive.	Nodine 1990
Radiological examination of mammograms	3 experienced mammographers and 6 radiology trainees	40 sets of 2-view mammograms; in 20 cases, at least one malignant lesion visible on at least one view. Other 20 cases are free of lesions. Eye movements tracked as mammograms examined until lesion located.	Eye positions of experienced mammographers fixated more on true lesions than novices. .	Experienced clinicians detected true positive more thoroughly than novices, but dwell times before clinical decisions made were longer compared to novices. Prolonging the search yielded few new lesions and increased risk of error.	Nodine 2002

Table 2: Impacts of Visual Training Real World Search Tasks

Visual task targeted	Group receiving training	Training		Outcomes	Comments	Citation
		Method	**Replications**			
Airport baggage screening	72 screeners		20-minute sessions repeated weekly for 6 months	Increased detection ability 60% after 20 sessions, 71% after 28 sessions	Training difficulty dependent on viewpoint of prohibited item, superposition by other objects and bag complexity	Schwaninger 2003
Airport baggage screening	16 adults	Computer based study of four sets of 300 practice images	Five experimental sessions of 300 images each over	Small but statistically significant improvements in	Screeners were quicker to fixate on the target but not more likely to do so. Scanning became more efficient but not more effective. Authors conclude that training should not modify the scanning	McCarley 2004

		each; digitally inserted targets present in 20% of images	multiple days; last session presented fresh images only	sensitivity; faster response times for both target present and target absent trials	behavior but should focus on developing ability to perceptually recognize objects in security imagery. Training materials should be maximally heterogeneous ensure skill generalization.	
Airport luggage screening	36 university students	Computer-based images containing 1 of 5 distinct prohibited items.	Group 1: Memorize a set of 1 of 5 possible targets. Group 2: Memorize sets of all 5 possible targets. Training for each consisted of 4 sessions of 100 images each with targets present at 50% prevalence. Feedback provided after each image.	Day after training, Groups shown images containing novel target for test of performance. Group 1 (trained on higher diversity of targets) exhibited significantly higher hit rate on novel target than Group 2 or control group.	The higher diversity of target search objects during training resulted in higher hit rate against a novel target.	Gonzalez 2011
Airport baggage screening	40 university students	Computer-based discrimination testing; two images presented simultaneously; searchers tasked with identifying if IED threat items were identical across images	On average, 377 trials of images during a 30 min session	160-item test (63 with target, 97 without target) of performance with novel targets. Versus control group without training, authors report increases in speed and accuracy.	Impact of training was transferred to the detection of novel targets.	Schuster 2013
Baseball performance	19 players	Perceptual computer-based learning program consisting of training with a diverse set of stimuli, optimized stimulus presentation, multisensory facilitation, and reinforcing training stimuli	Thirty 25-minute sessions over course of 8 weeks, averaging 4 sessions per week.	Improved contrast sensitivity and visual acuity. Improved baseball performance versus previous year and league averages	Details of training available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3932179/	Deveau 2014
Radiological exam of chest CT scans	10 novices and 10radiologists	Multiple sessions viewing CT scans with 1 of 3 known lesions	4 sessions of 500 trials each	Novices improved sensitivity to lesion detection (via reduction of false positives) equal to that of experienced radiologists	No overt training per se; experience gained because of participation in study	Nakashima 2013

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[THIS ARTICLE WAS NOT PEER REVIEWED, BUT HAS BEEN SUBMITTED AS A COMMUNICATION OF RESEARCH]

ECHO: Developing a multi-hazard incident risk assessment tool for swiftwater and flood rescue

Steve Glassey

Country Fire Authority

Victoria, Australia

Email: steve.glassey@hotmail.com

Abstract

Currently there is no multi-hazard risk assessment tool for determining the level of complexity to swiftwater and flood rescue incidents. Traditionally, the International Scale of River Difficulty is used but it is primarily for whitewater paddlers for use in a recreational context, without much consideration to the multitude of hazards faced in swiftwater and flood rescue environments. In response to this gap, the ECHO risk assessment tool has been developed and undergone initial testing. This tool provides for simple and rapid codification of multiple hazards and response considerations and is globally applicable. The tool also assigns a final risk assessment colour making the interpretation of the assessment easy to understand and communicate. Though the proposed tool shows potential, further research is needed before it should be operationalised.

KEY WORDS: *Assessment, echo, flood, rescue, risk, swiftwater, tool, srirac.*

Introduction

Throughout the world, the International Scale of River Difficulty (ISRD) (American Whitewater, n.d.) has become the standard to rate the degree of difficulty and risk to whitewater kayakers, raft guides and other river users, also known collectively as “paddlers”. The scale is part of the American Whitewater Safety Code and was developed by an experienced cadre of whitewater experts from the American Whitewater, a national non-profit river conservation organisation founded in 1954.

It has played a vital role in consistently providing a tool across different countries to rate river paddling complexity including specific features or sections within. There are minor variations in its application outside the United States, with some countries like New Zealand referring to the scale as “Grades” using numbers 1 to 6 (Maritime New Zealand, 2015, p. 26), not the prescribed “Classes” (using Roman numerals I to VI) which is inconsistent to the international terminology and may raise confusion over whether another international system exist. Likewise, it has been referred to as the International

Whitewater Scale, International River Grading System, and International River Rating System adding to the confusion. The scale ranges from one to six, with six being considered extreme.

Class I: Easy	Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
Class II: Novice	Straightforward rapids with wide, clear channels which are evident without scouting. Occasional manoeuvring may be required, but rocks and medium-sized waves are easily avoided by trained paddlers. Swimmers are seldom injured and group assistance, while helpful, is seldom needed. Rapids that are at the upper end of this difficulty range are designated Class II+.
Class III: Intermediate	Rapids with moderate, irregular waves which may be difficult to avoid and which can swamp an open canoe. Complex manoeuvres in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims. Rapids that are at the lower or upper end of this difficulty range are designated Class III- or Class III+ respectively.
Class IV: Advanced	Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast manoeuvres under pressure. A fast, reliable eddy turn may be needed to initiate manoeuvres, scout rapids, or rest. Rapids may require "must make" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. For kayakers, a strong roll is highly recommended. Rapids that are at the lower or upper end of this difficulty range are designated Class IV- or Class IV+ respectively.
Class V: Expert	Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex, demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. Proper equipment, extensive experience, and practiced rescue skills are essential. Because of the large range of difficulty that exists beyond Class IV, Class V is an open-ended, multiple-level scale designated by class 5.0, 5.1, 5.2, etc. Each of these levels is an order of magnitude more difficult than the last. That is, going from Class 5.0 to Class 5.1 is a similar order of magnitude as increasing from Class IV to Class 5.0.
Class VI: Extreme and Exploratory Rapids	Runs of this classification are rarely attempted and often exemplify the extremes of difficulty, unpredictability and danger. The consequences of errors are severe, and rescue may be impossible. For teams of experts only, at favourable water levels, after close personal inspection and taking all precautions. After a Class VI rapid has been run many times, its rating may be changed to an appropriate Class 5.x rating.

Table 1: International Scale of River Difficulty (American Whitewater, n.d.)

Issues with the current scale

As the ISRD was developed for paddlers such as those involved in rafting and kayaking it still has some application to swiftwater rescue (Ray, 2013, p. 22), but it also has some limitations to assess risk for urban flood incidents such as those involving low head dams (weirs), flood channels/aqueducts, and rescues from vehicles.

The primary element in determining the river classification is the waves or rapids, though the degree of danger to the swimmer is also considered. However, in some urban flood situations that are highly dangerous there may not be any significant waves or rapids, such as in low head dams or flood channels. By using wave characteristics alone, a highly dangerous fast flowing flood channel with minimal wave characteristics could be designated as Class I.

With respect to flood channels, Gary Seidel (cited in Ray, 2013, p. 177), developed a 1 to 4 scale for "Classification of vertical wall flood channels" using the components of speed, depth and hazards (Table 2). Only one of the three areas (speed, depth or hazard) is required to be present to be assigned to that Class, i.e. a flood channel with a speed of 25 MPH with no obstacles, and less than 10' deep is to be considered Class III. Though simple to use, the limitation to four classes may be confused with the ISRD, where a Class IV using the Seidel classification is considered "extreme", but a Class IV using the ISRD is only considered "advanced".

Class	**Speed**	**Depth**	**Hazards**	**Rescue Option**
Class I	0-10 MPH	Less than 10'	No obstacles. No gradient.	Low risk options usually work
Class II	10-20 MPH	Less than 10'	Few obstacles. Has a gradient.	Some low risk options may work, row options better.
Class III	20-30 MPH	10-20'	Numerous obstacles	Higher risk options are usually required such as helicopters.
Class IV	30+ MPH	> 20'	Stair step channel, low head or rubber dams present	Extreme caution is required.

Table 2: Adaptation of the Seidel Flood Channel Classifications (cited in Ray, 2013, p. 177)

The Seidel classification also mentions low head dams being present, but these can be equally as dangerous as they can be benign, potentially leading to over-estimating the risk which may adversely prevent rescue intervention.

In the United Kingdom, much solid work has gone into a "Weir Assessment System" developed by Rescue 3 Europe and Natural Resources Wales (Rescue 3 Europe, 2016). The system is available in English, French, German, Italian and Hungarian. This assessment system is well regarded and is ideal to assist with risk assessment as part of pre-planning for response to weirs (low head dams). However, it is limited by its complexity for real time rescue risk assessment given it requires five pages of formula to be calculated using the components of hazards, likelihood to cause harm, risk rating and difficulty of rescue to generate a weir rescue difficulty score.

Despite the International Scale of River Difficulty (which is for paddlers on rivers), Seidel flood channel classification system, and the Weir Assessment System, there still is no common risk assessment able to cater generically for the multi-hazard nature of swiftwater and flood rescue. It was this dilemma that prompted the author to develop a coding system for swiftwater incidents that is also capable of generating an overall risk level (colour).

Swiftwater Rescue Incident Risk Assessment Codes

With the popular adoption of the ISRD, it is reasonable to expect that responders to swiftwater incidents should be familiar with the one to six classification system (ISRD), and know that the higher the number, the higher the risk. This creates the basis for the proposed ECHO Swiftwater Rescue Incident Risk Assessment Code (SRIRAC), a three digit code with the first three components making up the risk assessment using a one to six scale. The final component (Outlook) provides an assessment to whether the risk is stable or likely to escalate or de-escalate.

The Swiftwater Rescue Incident Risk Assessment Code has four key components using the Acronym ECHO, namely:

- Entry
- Class
- Hazards
- Outlook

The Entry, Class and Hazards make a three digit code, and is suffixed with an Outlook designation that being an up arrow (↑) to denote the risk is increasing (escalating), or a down arrow (↓) denoting the risk is reducing (de-escalating. Where no arrow is added, this denotes the risk is stable (unlikely to significantly change).

Entry

The degree of difficulty for a swiftwater rescuer to enter the water flow (hot zone) is scored (table 3). The degree of difficulty to egress/exit the flow is considered next in the remaining ECHO components as limitations in self-rescue and flow speed for example factor into this.

0	Easy to enter, with little to no effort
1	Able to enter, may require effort
2	Able to enter, may require simple assistance
3	Able to enter, only with simple assistance
4	Difficult to enter, requires technical assistance
5	Very difficult to enter, even with technical assistance
6	Unable to gain entry

Table 3: ECHO Entry score

Class

Based on the hydrological features, the flow is assessed in accordance with the ISRD or this simplified table (table 4).

0	No flow (stationery water)
1	Fast moving, ripples often present
2	Straight forward hydraulics or waves
3	Moderate, irregular waves or hydraulics
4	Intense but predictable waves or hydraulics
5	Obstructed or very violent rapids or hydraulics
6	Extreme or non-navigable

Table 4: ECHO simplified classification of river

Hazards

Beyond the Entry and Class, the third component of the SRIRAC is Hazards as part of the ECHO acronym and is determined using a supplied table (Table 6). This table provides sub-components of typical hazard categories that are encountered in swiftwater and flood rescue environments. Wherever an environment during assessment meets any of these, the highest scored hazard provides the final score ranging from zero to six to be used in the three digit SRIRAC.

Self Rescue

Using a typical swiftwater responder (i.e. someone trained against DEFRA Training Module 2 – Water and Flood First Responder (DEFRA, 2019) or other similar training levels) as the skill base of assessment, the ease of self-rescue is assessed if the responder was to enter the water with basic protective equipment such as helmet and personal floatation device.

Flow Speed (velocity)

Using average walking, running and sprinting speeds to make assessments easy to perform in the field, the speed of the flow is measured. This can easily be done by throwing a stick or other buoyant object into the flow and seeing how fast it travels, often using a person moving in parallel on the river bank. Some flood channels and aqueducts are capable of very high speeds and this is also factored into the scores available. High speed flow even in shallow water can knock a person off their feet.

Depth

The depth of water also affects the risk with more surface area of rescuers exposed to flow forces especially on the body (Table 5). The depth also can affect the stability of vehicles and persons due to the changes to buoyancy states (positive, neutral or negative). An example is that a vehicle in shallow water is likely to be more stable than it is in deeper water.

Current Velocity **Kmph**/Mph	*On Legs* **N**/lbf	*On Body* **N**/lbf	*On Swamped Boat* **N**/lbf
4.8/3	**75**/16.8	**149**/33.6	**752**/168
9.7/6	**299**/67.2	**596**/134	**2989**/672
14.5/9	**672**/151	**1343**/302	**6726**/1512
19.3/12	**1196**/269	**2392**/538	**11957**/2688

Table 5: Force of water (adapted from Swiftwater Rescue, by Slim Ray) (Ray, 2013)

Contamination

It is common for flood water to be contaminated by a wide range of sources. This could include sewage, effluent, chemicals, oils and fuels and many more hazards. Increasing thresholds of water quality is used to assess contamination from the lowest score (0) given to rivers that are known to provide safe drinking water. The risk score increases for this sub-component using the Permissible Exposure Level as the benchmark, though in the field this can be subjective without necessary testing equipment. Though not directly affecting human health, biosecurity considerations are included in the sub-component to acknowledge the need for decontamination processes following exposure above a score of 2 or higher. If water-borne diseases are present such as cholera, typhoid, leptospirosis etc, these automatically render the contamination sub-component a minimum score of 4.

Wildlife

In some parts of the world, wildlife may pose a risk to performing swiftwater or flood rescues. Some animals may pose a nuisance such as goats that may take an unwelcome interest in consuming rope anchors, vector-borne diseases such as Malaria, Dengue Fever, Ross River Fever etc, through to apex predators taking the highest risk score.

Temperature

Cold water affects human performance and survivability in water. The colder the operating environment, the more difficult such rescues can become. The temperature sub-component uses 20°C or above as the lowest risk based on normal physiological adaptations occurring in water with a temperature between 20-25°C, then stepping up to disorders in physiological response occurring below 20°C, then using 12°C as typical sub-tropical average sea temperature, following by using 6°C (43°F) as the next threshold based on the Golden and Tipton (Tipton & Golden, 2011) decision making model[1], and the highest risk score assigned to below freezing level (of fresh water). The temperature sub-component factors in decreased physiological performance and survivability. It should be noted the SRIRAC is not used to determine the mode of the incident (i.e. rescue vs. recovery) and guidelines such as Golden and Tipton's (Tipton & Golden, 2011) (6:30:90) or DEFRA rescue or recovery decision making models (DEFRA, 2019) should be used. The alternate means to assess the temperature risk is using thermal demand which may take into consideration air temperature, water temperature and type and amount of personal protective equipment worn, the level of physical activity or inactivity encountered during the rescue that may lead to hypothermia or hyperthermia. The Tipton et.al. (Tipton, Abelairas-Gómez, Mayhew, & Milligan, 2020) study on the thermal demands of flood rescue and impacts on task performance provides more detailed information on this topic.

[1] The Golden and Tipton (2011) decision making guide (also known as the 6:30:90 guide) suggests that if the water temperature is warmer than 6 degrees Celsius their survival/resuscitation is extremely unlikely after being submerged for longer than 30 minutes; or 90 minutes in colder water.

Imminent Hazards

Finally, for this sub-component there is as catch-all to ensure imminent or actual hazards not already listed can be scored and factored into the risk assessment.

Outlook

The outlook provides an indication whether the swiftwater rescue risk, based on any of the three primary ECHO components, is likely to increase in risk (escalate) or is likely to decrease in risk (de-escalate) in the window of time to carry out the rescue. The outlook uses the up and down arrow symbols respectively, and where the incident is deemed stable (unlikely to change), no symbol is used. The approach to use arrows for escalation and de-escalation is adapted from the New Zealand Coordinated Incident Management System (New Zealand Government, 2019).

ECHO Colour

The ECHO colour allows any SRIRAC combination to be easily translated into an overall risk colour. Using a simple five colour approach:

Green	Low	No component exceeds a score of 1.
Yellow	Medium	Any component scored as 2
Orange	Medium Plus	Any component scored as 3-4
Red	High	Any component scored as 5
Purple	Extreme	Any component scored as 6

The use of the ECHO colour, following on from assigning a SRIRAC (code) allows for the rapid and simple communication of risk to other public safety professionals. For example, the first arriving responders on scene may code the incident as 352↑, which would be an "ECHO RED ESCALATING" as one of the components scored a 5 (in this example, the flow was Class V). Context can be given to the ECHO Colour such as "ECHO Yellow Low Head Dam".

This can help assign appropriate team types to the incident, with ECHO Green rescues generally being able to be performed using simple wading or shore based techniques. ECHO Yellow may be suitable for simple contact and boat based rescues, and ECHO Orange requiring more specialist expertise. ECHO Red are highly hazardous environments to carry out a rescue from even by experts, and ECHO Purple is extreme where entry to the water to carry out the rescue is un-survivable. The patient status or mass casualty triage code is not considered in the risk assessment, as the ECHO tool is primarily a tool for response personnel to assess the level of risk to perform a rescue.

Score	Self Rescue (Responder Level) Assessment[2]	Flow Speed	Depth	Contamination	Wildlife	Temperature	Imminent Hazards to rescuer if exposed[3]
0	Self rescue not needed	No flow speed (static)	Less than ankle	Water safe to drink		Above 20°C (68°F) but not hot enough to cause discomfort or low thermal demand	No other hazards identified
1	Self rescue easy	Less than walking speed (5kmph or 3mph)	Shin to thigh height		Nuisance wildlife not posing threat to safety	Between 12°C (43°F) and 20°C (68°F) or moderate thermal demand	
2	Self rescue may require effort	In between walking and running speed	Above thigh up to chest	Biosecurity hazard not directly affecting human safety (ie. didymo)		Between 6°C (43°F) and 12°C (54°F) or high thermal demand	Hazards that may hinder rescue (i.e. turbidity) or damage property
3	Self rescue difficult, may need help	Running speed (12.5kmph)	Above chest but less than 2m.	Contaminants under their PEL		Between 0°C (32°F) and 6°C (43°F)	Hazards that may cause minor injury
4	Self rescue limited, help required	Sprinting speed (25 kmph)	2-3 metres deep	Contaminants exceeding their PEL or known water-borne diseases present	Animals present that may threaten safety or carry vector causing illness	Below 0°C (32°F)	Hazards that may cause moderate injury
5	Expert assistance often required	25-50 kmph	Over 3 metres deep				Hazards that may cause major injuries or death
6	Rescue may be impossible or death imminent	Greater than 50kmph		Contaminants IDLH	Large predatory animals likely to attack		Imminent hazards highly likely to cause death or serious injury

Table 6: ECHO Hazards table

[2] This should also consider self rescue in the context of low head dams, aqueducts/channels, width of flow, etc

[3] May include utilities, engulfment, mechanical entrapment, intakes, strainers, solid ice, debris, suction hazards, vehicle stability etc.

Examples

As static images are not realistic to use for risk assessment, a number of video clips located on YouTube have been used to provide examples on how to apply the proposed tool. They have been assessed and assigned an ECHO Code and Colour (table 7).

Video QR Code	ECHO Code	ECHO Colour	Comments
	001	Green	Easy to walk into the water (hot zone) scores a 0; there is only stationery water giving the Class a 0; and the water appears to be between shin and thigh height scoring a 1 for hazards.
	002	Yellow	Easy to walk into the water (hot zone) scores a 0; there is only stationery water giving the Class a 0; and the water appears to be between thigh and chest height scoring a 2 for hazards.
	023	Orange	With pedestrian access it scores 0 for entry; the flow has straight forward hydraulics so it scored 2 for flow (but it could be reduced to 1 but erred on the conservative side); and given the depth of water to the vehicle and slow speed, it scores a 3 for hazards. No arrow is provided assuming the flow is stable.

	425	Red	With the requirement to use technical access the entry scored 4; the flow has straight forward hydraulics so it scored 2 for flow again; and given the difficult of self-rescue and flow speed, it scores a 5 for hazards. No arrow is provided assuming the flow is stable.
	156↑	Purple	Though easy to get into the flow (hot zone) and scoring 1 for entry, the flow has violent rapids and hydraulics (scoring 5 for Class); and the debris and inability to self-rescue puts this as an ECHO Purple. As a result, the rescuers opt for an aerial rescue using ropes. The bridge is slowly being washed away with the victims, so an escalating symbol is added.

Table 7: ECHO examples

Limitations and further research

The development of the EHCO multi-hazard risk assessment tool for swiftwater and flood rescue provides for rapid and simple scoring and coding of incidents. It is distinctly different from the ISRD to avoid confusion when used in a public safety context also. As a pre-print, the article was viewed over 208 times, downloaded over 124 times (Glassey, 2020) and informal feedback was received via social media channels to refine the concept. Despite this refinement, as a concept it requires further testing with end users and discussion with other experts.

Further testing may lend itself to a comparative analysis of focus groups given identical sets of scenarios to measure variations in subjectivity, and using focus groups with different levels of swiftwater rescue knowledge.

One limitation of the ECHO tool is that there is likely to be some variance in scoring due to being subjective in nature, however this is no different to the ISRD that also encounters the same limitation of subjectivity especially around the lower levels (Watters, 1999) and the persons perception of risk.

Another limitation of the ECHO tool is that is it primarily used as a single incident risk assessment, as opposed to a wide area flood rescue assessment, or provide a high level flood impact assessment like the Mercalli scale is used for earthquake impacts. However, in providing an ECHO colour code for each single incidents, response coordinators may be able to better triage incidents.

Discussion

When public safety responders arrive at a swiftwater or flood rescue incident, there is currently no simple and rapid system to codify the risk. With so many variables that require to be considered, the ECHO tool prompts the user to ensure a wide range of factors are considered and appropriately risk scored. A methodical approach in using the tool, should allow for first responders with minimal training to self-identify the risk level of the swiftwater incident and help response coordinators to triage multiple swiftwater incidents. The tool requires further piloting, discussion, and evaluation before being further operationalised, but initial examples show the potential it has to make on-scene risk assessments more robust, regardless of the environmental context.

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About the Author

Steve Glassey is a leading expert in swiftwater rescue having been involved in instructing in this discipline for over 20 years. He is appointed by the Coroner's Court of New Zealand as an Expert Witness for swiftwater and flood related fatalities. Having taught around the world including New Zealand, Oman, United States, and Australia, he has been active in developing new approaches to technical rescue including use of TEC REEP 8mm cord for swiftwater rescue applications and was awarded the Higgins & Langley International Flood Rescue Award in 2014 for co-authoring the first body recovery from swiftwater training programme. He was Rescue 3 International's Instructor of the Year (2014), and later became instrumental in founding the International Technical Rescue Association as the inaugural Chairman. He is an ITRA Level 3 Swiftwater Instructor (Advanced, Boat, and Vehicle). He continues to pioneer new swiftwater rescue methods such as shore based vehicle stabilisation and other swiftwater vehicle rescue techniques as he has a special interest in this area.

ORCID **ITRA**

Book Review: Billy, A. 2020. NORTH SHORE RESCUE: If You Get Lost Today, Will Anyone Know?

Friesen Press, ISBN 978-1-5255-8061-1. Ebook $10.99 US, Paperback 18.99 US, Hardcover $24.99 US

About the author: Allen Billy served as a North Shore Rescue volunteer team member for twelve years and participated in over 700 search and rescue operations in mountain, wilderness and urban environments. Allen has 30 years' experience in post-secondary education, primarily in Allied Health and Biology education, teaching a variety of Human Anatomy and Physiology and basic Biology courses. Allen has a doctorate in zoology, University of Texas at Austin, and BSc degrees (zoology) from University of British Columbia.

This book will be of interest to all those engaged or interested in volunteer search and rescue. Although the book focusses on one team – North Shore Rescue (NSR) in British Columbia – the issues, stories, frustrations, and humour described herein will be recognized by those in other areas.

Allen Billy takes the reader on a historic journey of NSR from its early days as a Civil Defense organization with barely adequate vehicles, equipment not suitable for mountain rescue and rudimentary communications, up to present time as a technical innovator and leader in Canadian search and rescue. As a volunteer team, NSR responds to requests for assistance from fire, police, ambulance service and municipal and provincial governments. Although NSR is an autonomous registered society, it nonetheless finds itself in the often complex and frustrating world of government and agency bureaucracy. Some of the narratives in the book show how accommodating to the myriad of bureaucratic requirements has been an evolution in itself.

Allen Billy has done a superb job of capturing compelling anecdotes and memories from North Shore Rescue team members and through them and along with his own memories and experiences, has woven a fascinating story of NSR's contribution to the community.

The book makes no pretense of historical or factual accuracy; rather the team members' narratives appear as they are remembered. Also, the author chose not to highlight the team's most dramatic or spectacular operations or focus on the contributions of any particular team member. As the author puts it: "I was interested in capturing a wide spectrum of memories and perceptions…as the people involved chose to tell the story". Also, the author warns: "This book contains profanity, politically incorrect statements and dramatic content associated with traumatic injury and death…. some stories may be troubling for readers."

In this series of narratives, the book portrays the broad cross section of the types of search and rescue operations undertaken from simple ground SAR to more complex helicopter flight rescue, swift water and advanced back-country medical intervention. It also captures the broad range of skills, attitudes and passions of the 40 or so members of North Shore Rescue; a mix that enhances the operational strength of this and all SAR teams.

Many of the stories told in this book show something of the selflessness and perhaps humbleness of the SAR volunteers in doing what they are trained to do at any time of day and in all conditions. Some readers will know that this ethic is shared by all volunteer SAR organizations – an ethic not commonly known or acknowledged by the general public or those whose actions have triggered the need for this life-saving service. At times the frustrations of inadequate recognition, and never seeming to get ahead of the curve through education and prevention comes through in the team members' recollections.

The book's narratives, and there are a lot of them, are told by a diverse group of volunteers, and fairly represent the complex make-up of the team. NSR has attracted members from many backgrounds, skill levels, ages, and both genders. However, all share a common purpose and passion – helping others. Some stories demonstrate the volunteers' mission-focus on operations, with individualities, and egos left at the trailhead.

Is SAR life disruptive? The book has many anecdotes from team members and spouses regarding the "disappearance" of team members to attend a call-out; often at 2AM or coinciding with a planned family or social event. As Allen describes, the family harmony can be severely strained when this happens. Of course, this is usually ignored at the time by the team member, naively believing that the call-out will always be more important than family. This is not necessarily the view of the abandoned spouse; however as some have explained, the abandonments, the frustrations, the inconveniences are eventually made up for by the realization that someone's life may have been at stake. Some, however, have described a period of frosty silence that pervades the household upon the eventual return of the team member. Allen fails to mention that to partly compensate for family inconveniences, NSR frequently hosts family get-togethers and outings in part to ensure no one spouse feels alone in the "great abandonment" common in SAR life and to allow those left behind a chance to see, and to some extent experience what front line SAR life is like.

Over the years NSR has found the need to establish several speciality groups. A dive team was formed early on mainly for body recovery and evidence searching, until the RCMP assumed this role. A dog team has been used off and on for many years, with team member dogs and police dogs utilized. The book relates several, sometime humorous, stories of inappropriate use of this resource. A kayak team has been very useful in rapid searching of the three main waterways in North and West Vancouver. The team's turn to helicopter assistance was a major leap in SAR technology for NSR. Use of helicopters for searcher deployment, aerial searching, and subject extraction has meant that the team can efficiently respond to the over 100 calls per year with its existing personnel. North Shore Rescue was the first SAR team in B.C to certify in Helicopter Flight Rescue Systems, and now with a local helicopter company has Forward Looking Infrared Radar, and night vision capabilities. The book does a good job chronicling how these innovations have helped in many aspects of SAR work.

The book also covers the darker side of SAR – dealing with the unhappy outcomes that all SAR teams have learned to cope with, death and injury. The book describes these as “disturbing memories”; an apt term as some of these experiences live a long time in volunteers’ minds. For North Shore Rescue members, these have included the recovery of 10 or so bodies from debris torrent events, and the only death experienced by the team during a training exercise. The book also describes the only serious injury to a team member during a search operation. Importantly, the author mentions the continuation of the search following the extraction of the injured team member – an example of the mission-focus that SAR teams must have to carry out their work, despite the associated traumas.

Readers familiar with SAR work will know that death and injury to those seeking help are not uncommon in SAR operations and can create psychological issue with some volunteers; even those who have been exposed many times to operations involving serious injuries and body recovery. These and other forms of personal trauma have led NSR to employ CIS counselling for its volunteers more and more frequently. The author could have explored this in more detail given the importance of this service in maintaining volunteers’ mental health.

Humour is described in the book as a counter to the darker side of SAR volunteering. Allen talks about the team’s annual Green Door Award, given to the team member who has made the most humiliating blunder that year. This is usually a mental lapse such as hiking past the party they were searching for or turning off the portable radio in order to conserve battery power and wondering why normal radio checks were not being made. The book also includes several quotes of team members which contain expletives and demonstrate some of the “black humour” that creeps into SAR work in part as a coping mechanism.

The book also touches on two activities that follow all SAR operations. The first is a traditional meal immediately after volunteers leave the field where team members relax, unload stress and undertake a very informal debriefing of the operation. One senior team member quipped: “It’s the tie that binds”, referring to the need to unwind from the stress and get ready for sleep or work. The second is the formal debriefing later on where all aspects of the operation are discussed, lessons learned, and improvements and adjustments are made.

The book would have benefitted from a broader treatment of the need for more effective outdoor safety education. Although the book describes the various outdoor safety programs offered by the team, it makes no mention of their effectiveness. With escalating call volumes, seemingly due to the same causes year after year, the reader may wonder whether the education programs are being effective.

All in all, this book is a worthwhile read, not only by those engaged in volunteer SAR work, but for outdoor enthusiasts who may one day be in need of this valuable service.

Ross Peterson,
Former member North Shore Rescue.

[THIS ARTICLE WAS NOT PEER REVIEWED, BUT HAS BEEN SUBMITTED AS A COMMUNICATION OF RESEARCH]

New Zealand Search and Rescue fatality data: Creating targeted prevention messaging.

Ken MacIver, BA, PGC (Para), PGC Health Prac Ed, PGC Resus, MPP, **Callum Thirkell**, BCA, BHSc (Para), PGC (Para), **Glenn Mitchell**, ICP, MPA, **Carl van der Meulen***, BA(hons) & **Elizabeth A. Asbury**#, BSc (Hons), MSc, Ph.D.

School of Health, Whitireia New Zealand, Porirua, New Zealand and *New Zealand Search and Rescue, Wellington, New Zealand.

E-mail: Elizabeth.Asbury@Whitireia.ac.nz

Abstract

Introduction: Whitireia New Zealand were commissioned by New Zealand Search and Rescue (NZSAR) to undertake a thorough analysis of all NZSAR related fatalities between April 2010 and July 2017. The purpose was to provide a high level overview of all fatalities, in-depth analysis of recreational fatalities and provide recommendations for prevention messaging where appropriate.

Method: The NZSAR data was comprised of 1542 cases with 42 fields. Missing data were evident in the majority of cases. Cases were coded into one of six prescribed categories: Land, Water, Wanderer, No incident/false alarm, Out-of-scope (suicide, criminal, disaster victim identification (DVI), aviation and outside SAR region), Uncertain. Land, Water and Wanderer fatalities underwent full demographic and thematic analyses, while Out-of-scope, No Incident/false alarm data received full demographic analysis and partial thematic analysis, where the data allowed.

Results: Annual fatality numbers remained constant. Gender disparity was evident (66% male). Land-based activities resulted in 194 fatalities. Five activities were most frequently associated with fatal events and accounted for 75% of the land-based fatalities: tramping (29%), hunting (15%), walking (12%), mountaineering (11%) and commercial (8%). Falls (31%), drownings (26%) and medical events (24%) accounted for 81% of fatalities. Water-based activities resulted in 320 fatalities, with boating (30%), commercial (27%) and swimming (22%) resulting in 79% of deaths. Eleven fatal wanderings fell into two distinct cohorts; children (45%) and the elderly (55%). Drowning was indicated in the majority of child wanderers (80%). Out-of-Scope activities resulted in 452 deaths, with suicides (41%) and DVI cases (40%) the most common.

Conclusions: Recommendations include the use of buoyancy devices when engaged in any activity close to water, education around falls prevention targeting tramping and mountaineering clubs, providing an emergency position indicating radio beacon (EPIRB) to each person on board a vessel, and education to specifically target Māori and Pacific communities in relation to water safety.

Keywords: Search and Rescue; Fatality; Prevention; Land; Water.

Introduction

Outdoor recreation is popular in New Zealand, and is promoted as an accessible and relatively low-cost activity to encourage 42% of New Zealanders who are insufficiently physically active (World Health Organisation, 2018). However, in a country as geographically diverse as New Zealand, outdoor recreation does present risk of injury and death. In the event of remote accidents, injury or missing persons, New Zealand Search and Rescue (NZSAR) teams are at the forefront of survivor recovery.

New Zealand presents unique and challenging terrain for both recreational activities and provision of search and rescue services. The number of rescue helicopters in New Zealand per km is approximately ten times that of Australia demonstrating New Zealand's diverse and difficult terrain (Ministry of Health, 2018). The Search and Rescue (SAR) sector is led by the New Zealand Search and Rescue (NZSAR) Secretariat who provide a link between the operational and strategic roles of New Zealand SAR. They support and advise the NZSAR Council who in turn provide high level oversight. They also provide leadership to the NZSAR Consultative Committee, comprised of a wide range of NZSR stakeholders including the Rescue Coordination Centre (RCC) and NZ Police.

The RCC and NZ Police provide operational coordination for the more than 11,384 people who assisted in search and rescue responses in 2016-17. The responders, 94% of which are volunteers, attended 2,643 incidents in 2016 –17 (NZ Search and Rescue Council, 2017).

SAR responses are led by one of two coordinating authorities. Category One incidents are coordinated by NZ Police, usually at a local level and involve land and close-to-shore marine SAR operations. Category two incidents are coordinated centrally by the RCC for incidents typically involving missing aircraft or vessels, tracking distress beacons and international search and rescue operations. RCC monitors a 30 million km^2 search rescue area around New Zealand, from the South Pole to Tokelau and half way to Chile (Rescue Coordination Centre New Zealand, 2017).

Whitireia NZ were commissioned by NZSAR to undertake an analysis of all NZSAR related fatalities between April 2010 and Jul 2017. The aim of the study was to provide a high-level overview of all fatalities, in-depth analysis of recreational fatalities and provide recommendations for prevention messaging where appropriate.

Literature Review

Accident reports and safety messaging

International

There are few if any published studies which present backcountry fatality data for an entire country. Most focus on a specific range of activities or geographical region, with the result that only a portion of total deaths are reported.

A study in the United States (US) presented data from a five-year period (1989 to 1993 inclusive) for victims attended by the Reach and Treat team servicing Mount Hood wilderness area (Schmidt et al., 1996). Fatality statistics were not given, but it was reported that six missions were for body retrievals. In Austria, changes in injury patterns of victims attended by the helicopter-based emergency medical system (HEMS) were compared over two three-year periods from 1998 to 2003 (Kaufmann et al., 2006). However, the fatality data was coupled with those who were categorized as 'critical, survival uncertain', meaning that the specific number of deaths was not stated. An analysis of sixteen years' worth of Search and Rescue (SAR) data (1992 to 2007 inclusive) from missions in National Parks in the US included fatality data (Heggie & Amundson, 2009). In the United Kingdom (UK) a study analysed mountain rescue casualties for the period from 2002 to 2006 and presented a breakdown of injury types, but excluded fatality data (Mort & Godden, 2010). In an Italian study, SAR records were used to identify injury and fatality trends in a particular sub-alpine region over the twenty year period from 1992 to 2012 (Ciesa et al., 2015).

New Zealand

Outdoor safety messaging in New Zealand has historically been undertaken by a variety of organisations. In 2009, a number of these organisations collaborated to create AdventureSmartNZ (AdventureSmart New Zealand, 2020), the purpose of which was to provide consistent safety messaging for land, snow, water, boating and air activities. The AdventureSmart website also provides a central repository where links to the foundation organisations can be accessed.

In 2016, the New Zealand Mountain Safety Council (NZMSC) published 'There and Back: An exploration of outdoor recreation incidents in New Zealand'. This was the first major publication which presented comprehensive injury and fatality statistics relating to outdoor activities, with the fatality data covering the seven-year period from 2007 until 2014. The data was split into five main categories: tramping; hunting; mountaineering; mountain biking; and trail running. Fatality statistics in the report were taken from coronial data. This is to date the only wide-ranging publication analysing land-based activities in New Zealand.

Previous studies looking at New Zealand fatality or injury data have focused on a much narrower range of activities, such as the relative mortality risk for alpine climbers in Aoraki/Mount Cook National Park (Malcolm, 2001). Malcolm's fatality data came from the Mountain Safety Council (MSC), the Department of Conservation and records from the NZ Coroner's office. Similarly, Monasterio, (2005) described the patterns and severity of injuries to alpine climbers, including fatalities. Visser & Campbell (2014) looked at records from Police SAR databases to determine which injuries were most prevalent in victims tended by SAR responders. Another study analysed causative factors leading to accidents and fatalities in 'led outdoor activities', that is activities typically facilitated by a professional organization for education purposes (Salmon et al., 2014). The data, which spanned the five-year period from 2007 to 2011 (inclusive) included six fatalities.

With regards water-based activities, Water Safety New Zealand publish an annual 'Drowning Report'. In a similar manner to AdventureSmartNZ, Water Safety NZ was formed by an association of organisations within the water safety sector to provide a central and consistent safety messaging voice. Members of the public can access consensus statement safety messages from, and web links to member organisations.

Maritime New Zealand produced the Safer Boating Guide, which provides clear, evidence-based messaging for members of the public (Maritime New Zealand, 2017). The guide advises that lifejackets should be worn at all times, and that two forms of waterproof communication devices should be carried, preferably tethered to the skipper. Water Safety NZ works closely with Māori groups and communities to promote meaningful and applicable messaging to people of Māori ethnicity who engage in water-based activities (Water Safety NZ, 2019). Additionally, AdventureSmartNZ provide a Te Reo (Māori language) version of the Boating Safety Code.

A small number of studies have investigated specific water-based activities. Bailey (2010) compiled a list of 50 sea kayaking incidents which occurred between 1992 and 2005, which included 14 fatalities. O'Hare et al. (2002) published a paper on mortality and morbidity in white water rafting in NZ. And Bentley and Page (2008) presented a decade's worth of injury data from the NZ Adventure Tourism sector. None of these studies had an overlapping data collection timeframe as our study, nor did they use the same databases, although they were reporting on some of the same types of fatalities.

To the best of our knowledge, our study is the first to analyse fatality trends from Police and SAR databases for all land-based activities which generated a SAR activation. It also appears to be the first to present NZ data for virtually all water-based deaths (excluding those occurring in swimming pools), as it would be very unusual for a water-based incident resulting in a fatality not to trigger a SAR activation.

Method

The initial data was comprised of 1542 events between April 2010 and July 2017 where NZSAR were activated and one or more fatalities were reported. NZSAR merged the Category One and Two databases, which provided the raw data for this study. The database contained approximately 43 fields, many of which were incomplete. Two fields provided a narrative description of the event. Narratives lacked uniformity, ranging from 2000-word descriptions to no given narrative. The database was cleaned to allow meaningful analysis, and cases were initially divided into six prescribed categories:

1. Land
2. Water
3. Wanderer
4. No incident/false alarm
5. Out-of-scope (suicide, criminal, disaster victim identification (DVI), aviation, outside SAR region)
6. Uncertain – for cases that did not clearly fit into one of the above.

Land, Water and Wanderer fatalities were considered to be within scope and were the subject of full analysis. Suicide, criminal, DVI, aviation, out-of-region and no incident NZSAR activations were considered out-of-scope but were still the subject of full descriptive demographic analysis and partial thematic analysis, where the data allowed. Events categorised as 'uncertain', were discussed in order to establish categorisation by consensus. The 72 cases that could not be categorised due to a lack of information were then referred back NZSAR. NZSAR made the decision to exclude these cases from the analysis due to a lack of accurate information.

Land-based classification

Fatalities were coded as land-based when death occurred while the victims were intentionally engaged in land-based activity. For example, a person who intended to walk along a riverbank, slipped into the water and drowned would be included in this category, because their primary intention was walking. Similarly, a person who was walking, but then entered the water while attempting to rescue someone else and drowned would also be included in this category, as the primary intention of the victim had been recreational walking.

Water-based classification

Fatalities were coded as water-based when death occurred while the victims were intentionally engaged in water-based activity. This category included: boating, swimming, snorkelling, kayaking, self-contained underwater breathing apparatus (SCUBA), fishing and net setting. 'Boating' included vessels of all sizes that were engaged in a recreational activity, from large fishing vessels to the smallest dingy. Jet skis were also in this category. 'Swimming' related to fatalities where the intention was swimming for recreation, while any activity that involved breath-holding, and use of a mask and flippers (with or without a snorkel) was categorised as 'snorkelling'. SCUBA was the term chosen for those engaged in underwater diving activities that involved compressed air tanks (or other gas mixtures). 'Net setting' was a category that emerged from the data, and involved checking or retrieving nets in tidal waters or river mouths, while ‘Fishing’ was for those who were engaged in fishing with a rod and line (fly-fishing or surf-casting), but were not involved in any other category.

Wanderers

Wanderers were defined as people of impaired cognitive capacity, associated with age, special needs or dementia and who left their last location without permission of their carer. All wanderer events involved a multi-agency activation, with many personnel engaged in the NZSAR response.

Categorisation

The located fatalities (883 cases) were then categorised by activity using a coding system, which indicated whether they were in-scope or out-of-scope. In-scope fatalities (431 cases) were assessed for sub-activities, cause of death and associated trends. Out-of-scope fatalities (452 cases) were sub-categorised by cause with a high-level overview provided. Following categorisation, demographic and thematic analyses were completed on each category, creating a demographic profile of victims while identifying trends and patterns from the narrative descriptions.

Terminology and missing data

The terminology used throughout the analysis, particularly in relation to ethnicity and behaviour, reflects the data labels used within the database. Demographic data was often empty, unclear or inconsistent and frequently unable to inform analysis. The database narratives and publicly available sources were used in an attempt to consolidate the data, although confirming data definitively using coronial reports was beyond the scope of the analysis.

Authors	Year	Years covered	Theme	Fatality data	Region	Notes
Schmidt et al.	1996	1989-1993	Various wilderness activities	Reach and Treat team mission records	US	
Malcolm	2001	1981-1998	Mountaineering	Department of Conservation (DoC), Mountain Safety Council (MSC) and Coronial files	NZ	
O'Hare, Chalmers, Arnold & Williams	2002	1983-1996	White water rafting	NZ Health Information Service (NZHIS)	NZ	
Monasterio	2005	Not specified	Mountaineering and rock climbing	MSC, DoC and self-reports from participants	NZ	Survey of participants with a follow-up survey four years later
Kaufmann, Moser and Lederer	2006	1998-2003	Various mountain-based activities	Helicopter-based emergency medical system (HEMS)	Austria	Fatality and 'critical, survival uncertain' data coupled together
Bentley & Page	2008	1996-2006	Adventure tourism	NZHIS and the Accident Compensation Corporation (ACC)	NZ	
Heggie and Amundson	2009	1992-2007	Various National Park-based activities	SAR database	US	
Mort & Godden	2010	2002-2006	Various hill country-based activities	Not included	UK	
Bailey	2010	1992-2005	Water; sea-kayaking	Various sources	NZ	
Visser & Campbell	2014	2010-2011	NZSAR operations	NZ Police SAR database	NZ	
Salmon et al.	2014	2007-2012	Various 'led' outdoor activities	New Zealand Outdoor education/Recreation National Incident Database (OER NID)	NZ	
Ciesa, Grigolata and Cavalli	2015	1992-2012	Various pre-alpine region activities	SAR database	Italy	

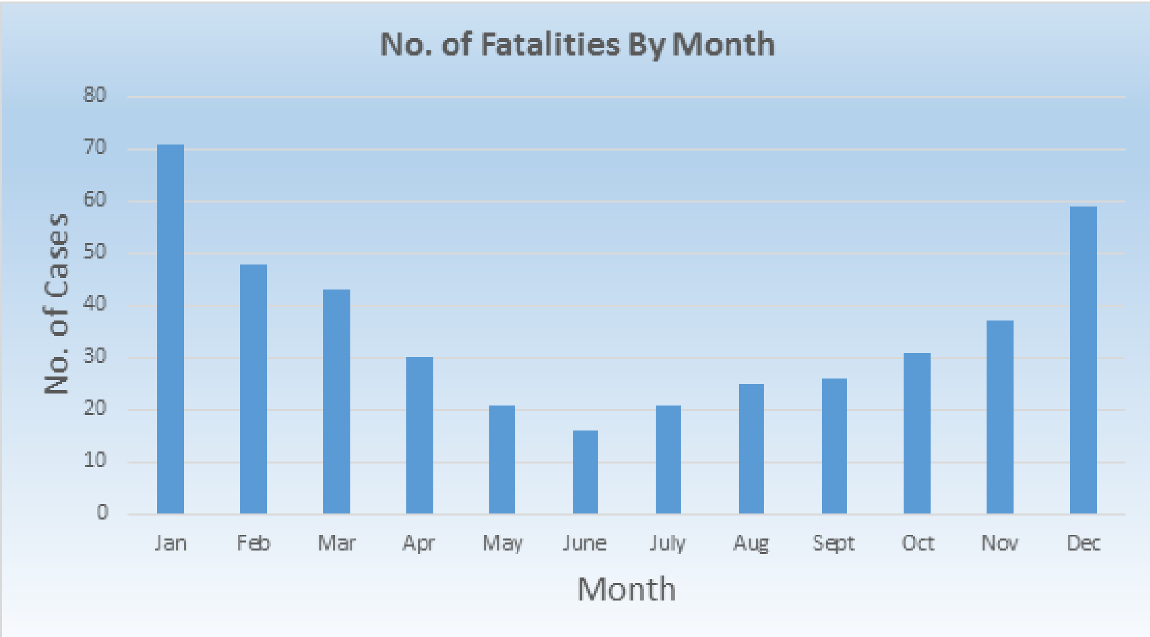
Table 1: *Studies involving injury and fatality data for outdoor activities*

Results

Of the 1542 NZSAR activations resulting in either no person located or a recorded fatality between April 2010 and July 2017, 883 involved at least one located fatality. Of these, 431 were categorised as 'In-Scope' (land, marine or wanderer), with 452 'Out of Scope' (suicide, criminal, disaster victim identification (DVI), aviation and outside SAR region). The remaining 659 cases were either not located, had no available information or were duplicates. Males accounted for 66% of all located fatalities. There was no significant difference in the number of fatalities by year. There was a clear increase in all fatalities during the warmer months of the year, due to an increase in outdoor recreation during this time (see Figure One)

Land-based activities

Figure 1: Total located NZSAR fatalities between April 2010 and July 2017 by month



Land-based activities resulted in 194 fatalities with a mean age of 45.2 ± 18.6 years. Males represent 75% of all fully documented land-based deaths. The majority of the deceased were engaged in walking activities such as: a multi-day tramping; day walks; dog walking; exploring coastal rocks (or similar) or fishing from land. In the case of those walking across rocks, the main cause of death was drowning after the victims were swept off the rocks by a large wave or slipped and fell into the water. Activities were initially assigned to one of twelve overall categories (see table 2), using the definitions as listed below.

Activity	No. of Deaths	Percentage of Deaths
tramping	**56**	**29%**
hunting	**29**	**15%**
walking	**23**	**12%**
mountaineering	**21**	**11%**
commercial	**15**	**8%**
other	**14**	**7%**
fishing	**10**	**5%**
riding	**7**	**4%**
intoxication	**7**	**4%**
skiing	**5**	**2%**
vehicle	**5**	**2%**
running	**2**	**1%**
TOTAL	**194**	

Table 2: *Land based activity resulting in death*

Land based fatalities were then analysed to determine how the activity ultimately resulted in death. The majority of land-based fatalities resulted from falls (30%), including many backcountry falls, where trampers, hunters and mountaineers fell to their deaths, and also falls from cliffs in urban areas. Only 2% of all land-based activities were recorded as a result of hypothermia. Fifty one land-based deaths occurred due to drowning (26%), further broken down into sub-categories (table 3).

Specifics of Drowning Deaths	No. of Deaths	Percentage of all Land-based Deaths
crossing river	**15**	**29%**
swept off rocks	**11**	**22%**
fell into water	**8**	**15%**
swept out to sea	**7**	**14%**
other	**10**	**20%**
TOTAL	**51**	

Table 3: *Breakdown of land-based drowning fatalities*

Medical events were the third highest cause and accounted for 46 deaths (24%). It is impossible to determine with certainty the exact medical cause from the database, but from the narrative it is clear that few were survivable unless they had occurred within a few minutes of a Tertiary Hospital.

Water-based activities

Water-based activities resulted in 320 fatalities with a mean age of 38.1 ± 17.9 years. Sixty-six percent of water-based fatalities were male. It is difficult to draw meaningful conclusion regarding ethnicity, as 36% of the data was either missing or inaccurate. However, Polynesian and Māori were over-represented accounting for 24% of the known deaths compared with 22% of the population (Statistics New Zealand, 2018). Table 4 shows the number of fatalities by water-based activity.

Activity	*No. of Deaths*	*Percentage of Deaths*
recreational boating	**96**	**30%**
commercial	**85**	**26%**
swimming	**71**	**22%**
snorkelling	**16**	**5%**
kayaking	**15**	**4%**
SCUBA	**14**	**4%**
net setting	**13**	**3%**
unknown	**4**	**1%**
fishing	**3**	**<1%**
other	**3**	**<1%**
TOTAL	**320**	

Table 4: *Fatalities by water-based activity.*

Of the recreational boating fatalities, 62% occurred in a coastal environment (less than five kilometres from the coast of mainland New Zealand), 28% in blue water (more than 5 kilometres off the coast) and 10% in fresh water lakes or rivers. A breakdown of factors contributing to all water-based fatalities was limited due to missing data. Nevertheless, data from 116 fatalities (36%) are detailed in table 5.

Contributing factors	*Number of Deaths*	*Percentage of Deaths*
swept out to sea	**35**	**30%**
no life jacket	**18**	**15%**
alcohol or drugs	**13**	**11%**
medical	**12**	**10%**
jumping	**9**	**8%**
inexperienced	**6**	**5%**
bad weather	**5**	**4%**
other	**18**	**15%**
TOTAL	**116**	

Table 5: *Factors contributing to water-based deaths.*

Wanderers

Eleven fatalities were as a result of wandering incidents. Wanderers fell into two distinct age categories, children (45%) and the elderly (55%). Following thematic analysis, it was identified that both age categories were associated with distinct behaviour and terminology. Therefore each age group was analysed independently.

Children

The children involved in fatal wanderer events were aged between three and 11 years of age, predominantly male, with 80% of Māori or Polynesian decent. Of the five child wanderers, three were known to be autistic. Three were reported missing from their homes, while two absconded during recreational activities with their families. All were under the care of at least one family member at the time of their disappearance. All child wanderers were located in close proximity to their last known location. Eighty percent drowned in water hazards known to the child.

Adults

The adults involved in fatal wanderer events were aged between 64 and 87 years of age, male and were either of Māori, Asian or Caucasian decent. Of the six adult wanderers, all were known to suffer from dementia. All were reported missing from their family home or an aged care facility.

Adult wanderers were located in a variety of locations, some within the immediate vicinity of their last known location, and others up to 22 kilometres away. Fifty percent drowned after falling into water hazards. The remainder died as the result of accidental trauma or were not found.

Out-of-scope activities

Deaths attended by NZSAR that fell outside the remit of the study were defined as 'Out-of-scope'. There were 452 out-of-scope events, which represented 29% of deaths within the database. These fatalities were the subject of demographic analysis to provide frequency data and context. The fatality events fell into seven broad categories: Disaster Victim Identification (DVI); Suicide; Outside the NZSAR geographic region; Aviation; Criminal; Commercial; and Unknown (table 6). Fatalities were assigned to each category primarily on the basis of the person's activity at the time of death, or where this was unknown, on the basis of NZSAR involvement.

Activity	*No. of events*	*Percentage of Out-of-Scope events*
Suicide	**187**	**41%**
DVI	**183**	**40%**
Aviation	**44**	**10%**
Outside Region	**25**	**5%**
Criminal	**8**	**2%**
Commercial	**3**	**1%**
Unknown	**2**	**1%**
TOTAL	**452**	

Table 6: *Out-of-scope fatalities*

Discussion

Land-based activities

In many instances, the distinction between tramping and walking is problematic. Tramping was defined as a walking excursion that involved any of the following: remote or sub-alpine terrain; a multi-day outing; or terrain that was otherwise challenging enough to resemble the rugged terrain typically associated with the backcountry. The 56 tramping deaths in this study is comparable with the 45 fatalities over 7.5 years recorded in the MSC report (Mountain Safety Council, 2016).

"Lost footing. Couldn't self-arrest. Fell to death." In North America this sequence results in death so frequently that it has become an official phrase (Gonzales, 2003). The highest proportion (31%) of the Land-based deaths were secondary to falls, and it is reasonable to assume that many of the accidents occurred due of the mechanism described above. New Zealand's sub-alpine zone, typically occurring between 1200 and 1500 metres, consists of challenging terrain that can be as dangerous as the high mountains, while not appearing to be so (Mulheron, 2015). Sub-alpine terrain lends itself to slips and falls, which are then more likely to have fatal consequences. This may be because it is accessible to those who are less experienced, and partly because of the rugged and uneven terrain.

McCammon (2001) describes two types of backcountry learning environments: the first is where feedback from decisions is *progressive*; and the second is where it is *catastrophic*. In the latter setting the decision to cross a marginal river, for example, is an 'all-or-nothing' venture; either the party are capable of the crossing or they are not. McCammon emphasises that "…catastrophic environments are poor places to learn through trial-and-error" (p. 8). A marginal rise in river level can create a catastrophic learning environment due to an unexpectedly large increase in water force: this acts both directly by applying force to the person crossing, and indirectly by decreasing foot traction on the river bed secondary to increased buoyancy (Federated Mountain Clubs, 2012).

Hypothermia was a leading cause of death in remote New Zealand prior to the 1960s (Tararua Tramping Club, 1991), but has become proportionally less common (2% of NZSAR land-based fatalities). The reasons for this decrease are multifactorial, but include: improvements in outdoor clothing; decreased rescue times; increased performance abilities of rescue helicopters; improvements in weather forecasting; and the advent of specialised rescue teams which are able to operate on narrower safety margins, according to a conversation with an expert in outdoor recreation (Barnett S 2017, personal communication). The 'Trauma Triad of Death' is a term coined to describe the lethal combination of hypothermia, acidosis and coagulopathy which can lead to a vicious downward spiral for trauma patients with significant bleeding (Mitra et al., 2012). However, in the last 20 years substantially more of these patients have been surviving, largely due to early access to advanced medical care at tertiary trauma hospitals (Mitra et al., 2012).

Water-based activities

Kalafatelis et al. (2014) suggest that females are more likely to place importance on checking marine weather forecasts, avoiding alcohol and have a higher regard for lifejacket use than male recreational boaters. Their data also show that participation rates for recreational boating are higher for males (35%)

than females (22%). It was therefore expected that NZSAR recorded deaths for males would be higher than females, however a death rate of 5% for females is significantly lower than anticipated. The Watersafe organisation presents similar numbers, consistently reporting that over the past seven years, approximately 80% of drowning victims are male (Water Safety NZ, 2017). Males exhibit more risky behaviour than females (Harris et al., 2006), and among those who participate recreational boating, men have been identified as more likely to boat alone (Kalafatelis et al., 2014)

The majority of boating deaths were as a result of the vessel capsizing. In a number of cases those involved had floatation devices and/or emergency position indicating radio beacons (EPIRBs), but were unable to use them because of the speed of the event (EPIRB underneath capsized hull or swept away). Carrying an avalanche transceiver in a pack, rather than on your person, can result in failure due to the device not being accessible, or not in proximity to the victim if their pack is torn off. This is a similar issue to the EPIRBs being available, but not accessible after a capsize event. Avalanche transceiver manufacturers therefore recommendation having them attached to your person, not stowed in your pack. A similar recommendation might be prudent for recreational sailors.

Wanderer fatalities

Wanderer fatalities represented a small proportion of those contained within the NZSAR database but resulted in a substantial investment in terms of time and resources. All wanderer events, and especially those involving missing children, triggered a multi-agency response coupled with a substantial community involvement. The time between the wanderer being identified as missing and the emergency services being informed varied widely, from almost immediately to five hours after the disappearance. This was not associated with the age of the wanderer or whether the wandering originated from a home location or elsewhere. Social media was often also used to alert the community and distribute information. All adult wanderers had impaired cognitive capacity, but there was no indication of negligence on behalf of those responsible for their immediate care.

While the narratives contained within the database are written with appropriate objectivity and detachment, there is a tangible sense of distress and disappointment at the death of a missing child. Although an occupational hazard, attending such events has significant mental health implications for attending personnel (Collopy et al., 2012). Appropriate resources should be made available to NZSAR and emergency services personal in order to manage the personal impact of being involved in such traumatic events.

Out of Scope

The out-of-scope fatalities represented a large proportion of the total number of fatality events involving NZSAR. Of the seven broad categories that comprise the OS data, fatalities identified as suicides were the most prevalent, resource intensive and time consuming. Many involved extensive land searches involving NZSAR and community volunteers, body recovery from remote or inaccessible locations, or unpleasant and traumatising recovery of remains following impact suicides. NZSAR involvement was often triggered by reports of a missing person, eventuating in a suicide recovery. Demographic analysis has identified an over representation of New Zealand Caucasian males in all out-of-scope subcategories where the data is available. Previous research has identified that men are at far higher risk of suicide than women (Freeman et al., 2017), which supports the NZSAR data, whereas little information exists on gender disparities among the natural deaths requiring DVI.

Limitations

The database was comprised of routinely collected data, which was often incomplete. It was beyond the scope of the study to corroborate information with other databases such as coronial data or hospital records. The database only includes deaths involving a NZSAR response and does not capture all outdoor recreation related deaths. Activity categorisation was based on expert opinion and understanding of the literature, as there is no standardised definition of tramping and walking, or different types of boating. This study represents deaths in the unique terrain and population of New Zealand and results are not necessarily generalizable internationally.

Recommendations

Public messaging

1. Specifically target the Māori and Pacific communities in relation to water safety.
2. When boating, always wear a floatation device; put it on prior to getting onto the boat and only remove it once back on land.
3. The skipper of any boat to carry an EPIRB on their person at all times.
4. An EPIRB or personal locator beacon (PLB) be carried by each boat crew member, especially those engaged in blue water travel (more than 5 km off the coast).
5. Use buoyancy devices when planning to engage in an activity on the rocks or on a riverbank, such as fishing, surfcasting or exploring cliffs.
6. Use buoyancy devices when net setting or fishing on estuaries or at river mouths regardless of the perceived water depth
7. Create an education programme around fall prevention for trampers, day walkers and mountaineers.

NZSAR messaging

1. When searching for wanderers, immediate water hazards such as swimming pools, rivers or coastlines should be an urgent priority.
2. When searching for child wanderers, inaccessible locations (such as well secured private swimming pools) should not be discounted.
3. Ensure NZSAR staff have appropriate resources for managing the psychological impact of trauma.

Conclusions

The data highlights the importance of buoyancy devices whilst undertaking both water and land-based activities, including net-setting and fishing from rocks. Immediate water hazards are associated with wanderer fatalities, while falls and slips are associated with land-based fatalities. While the database was incomplete, with missing data skewing all analyses, the data suggests that significant fatality rates are present for Māori and Pacific peoples in water recreation, and that water safety advice should be targeted towards these specific populations.

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Abbreviations

DVI	Disaster Victim Identification
EPIRB	Emergency Position Indicating Radio Beacon
NZ	New Zealand
NZSAR	New Zealand Search and Rescue
PLB	Personal Locator Beacon
RCC	Rescue Co-ordination Centre
SAR	Search and Rescue
SCUBA	Self Contained Underwater Breathing Apparatus

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