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Published in:
Policing: a Journal of Policy and Practice

DOI:
10.1093/police/paad037

Publication date:
2023

Original Article

The Body Recovery From Water Study: The application of science to missing person search

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Abstract Missing person behaviour datasets indicate that a significant proportion of those reported missing are subsequently found deceased in water. Despite this, information about how human bodies move in an aquatic environment is limited. Created by a serving police officer and police search advisor, this study involved the collection and analysis of quantitative and qualitative data relating to deceased human bodies found in inland water. The analysis of this data was further enhanced by experimentation. The research aimed to identify factors that might affect body movement in water and to establish if these variables could determine search parameters more effectively and increase the chances of successful search operations and associated investigations. In this manuscript, the search and investigation approach is introduced and the key findings and implications of the application of natural sciences for police practice are discussed.

Introduction

Missing person incidents are an emotive and critical area of policing. Waiting for news or seeking answers about what may have happened to the missing person in their absence is deeply traumatising and has a significant impact on families and loved ones (Biehal *et al.*, 2003; Parr and Stevenson, 2013). The primary aim of a missing person search is to locate the individual alive at the earliest opportunity, but if they are deceased it is essential to recover their bodies as swiftly as possible. Expeditious recovery could be the difference between life and death if a body is located quickly using targeted search in defined areas within the 90 min survival time window (Tipton and Golden, 2011) which can allow the person to be resuscitated. Critical goals beyond preservation of life include the reduction of risk to recovery operatives, to reduce pain and suffering for families and to aid the missing person investigation. Increasing the effectiveness of the search operation can be the difference between recovering the remains of a missing person or not and/or ensuring that evidence is located which may otherwise have been

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Advance Access publication: 1 July 2023
Policing, Volume 17, pp. 1–8
doi: https://doi.org/10.1093/police/paad037

lost. Timely evidence gathering can impact upon the protection of, and reassurance of our communities, the investigation of crime and bringing offenders to justice.

The growth of evidence-based policing in the past decades has greatly influenced decision making (Huey and Mitchell, 2016) and has generated the use of terms such as 'scientific knowledge' in relation to police practice. However, the reference to 'science' in relation to police practice is commonly social science research and there is little evidence of the natural sciences being used for the advancement of police practitioner knowledge, although it has proven to become core for the work of the forensic scientist.

As an aid to planning search operations, police and their partner agency search organisations have traditionally used a range of data sets based on behavioural analysis and geographic profiling to try to predict missing person actions on land. These studies, which were created specifically for search practitioners, focus on the behaviour, and predicted movements of missing people (Gibb and Woolnough, 2007; Perkins *et al.*, 2011; Eales, 2016) or perpetrators (Burton, 1998) and seek to assist in establishing high probability geographical areas in which to direct a missing person search operation. The data are categorised by the perceived or diagnosed physical and/or mental state of the missing person and trends are identified to assist with search planning. Examples of such categories are children (in various age brackets), people with medical conditions such as autism or dementia and individuals who are depressed and potentially suicidal. Additional factors include the gender of the subject and what form(s) of transport may have been accessible to them at the time they went missing. The information is used alongside lifestyle information relating specifically to the individual as the underpinning of a search strategy.

Statistics show that if a person is missing or absent, either through their own agency or by the actions of a third party, there is a high likelihood that they may be found in water, especially if they are deceased (Burton, 1998; NPIA, 2007; Gibb and Woolnough, 2007; Perkins *et al.*, 2011; Holmes, 2012; Eales, 2016). Research in the UK demonstrated that 89% of men who had gone missing on a night out and had been subsequently found deceased, were in water (NCA, 2015). However, very little work has been carried out to explore the likely movement of a body in a water environment (Molenaar, 2006; Gibb and Woolnough, 2007) and there is little (if any) academic research aimed at locating missing people in an aquatic environment at the earliest opportunity. The consequence of this knowledge gap is that there is little documented evidence on which to base search planning, forensic or investigative decisions. A majority of the research that can be found on the way bodies move in water has been conducted on opportunistic samples or has employed the retrospective use of records (i.e. post-mortem files) consequently it is difficult to find a scientific project aimed specifically at establishing the likely movement of bodies in water. Many of the studies relating to bodies in water are aimed at progressing the fields of anthropology and pathology (Reh, 1967; Payne and King, 1972; Haglund, 1993; Anderson and Hobischak, 2004; Zimmerman and Wallace, 2008; Heaton *et al.*, 2010), which although useful in understanding some of the phenomena around body movement in water cannot be directly applied to the field of search, rescue and recovery.

This literature review has revealed influences on the likely buoyancy of human bodies such as the potential movement that may occur during the 'bloat' phase of decomposition (Reh, 1967) but this is supported with limited empirical data. A range of academic studies have more specifically defined stages of vertical body movement in water associated with decomposition and have sought to provide an order for these. The number of stages differ as does the terminology but the general order proposed by these researchers start with 'submerged fresh' or 'early floating' then list 'floating decay' and/or 'bloated deterioration' with the final stage being 'sunken remains' (Payne *et al.*, 1972; Zimmerman and Wallace, 2008; Barrios and Woolf, 2011).

Studies relating to the influences of hydrology on human analogues have provided a good foundation to be considered in missing person search cases (Dilen, 1984). As technology develops, the potential for the use of hydrodynamic modelling to predict where a body theoretically could be located is being discussed (Gonzalez *et al.*, 2022), however these studies do not consider the complexities of the variables associated with a human body and the interaction of these with the environment. A broad search of all literature with any potential relevance has resulted in an exploration of these fields and others including environmental physiology, anthropology, pathology, sports science, and textile construction.

The absence of data relating to body movement in water is detrimental to police search operations and subsequent investigations where a missing person is thought to be in water. To bridge the gap in scientific research in this area which can be utilised by practitioners in the field, the 'Body Recovery From Water Study' was established by the lead author in 2008 whilst working as a police practitioner in the field of search and recovery in hazardous environments. The project was established with the specific aim of collecting data to better understand likely body movements in an aquatic context and improve the practice of missing person search and investigation where a body is suspected to be in water. The 'Body Recovery From Water Study' is an ongoing project with continuing collation and analyses of data and supplementary experimentation.

This paper will introduce the 'Body Recovery From Water Study' and will examine preliminary observations made during exploratory analyses of the first 280 cases of field data and initial laboratory experiments. It will then focus on the benefits and challenges of the application of the natural sciences to advance knowledge for practitioners in the field of missing person search.

Phases of a missing person search

The search for the missing is split into three stages based on recognised practice:

- Initial Stage: Where to look in the early stages. For this research, this is the period shortly after the time of entry to the water and for the first 24 h.
- Subsequent Stage: 24 hours after the entry of the body into the water (or time of death), when decomposition of a body is more likely to become a factor.
- Exit Strategy: The rationale for reducing or altering search activity because the initial and subsequent search have not found the missing person.

In land-based search theory, initial search (sometimes called hasty search), (Dougher *et al.*, 1999) is wide-ranging spontaneous search activity in the most likely areas for a live missing subject. The length of time of this phase is not defined and it is left to the judgement of the police search advisor or search planner to decide when this has been completed. If the individual is not found during this phase, the search planner will then adapt the strategy to include a more detailed and systematic exploration of identified areas. Activities during the second subsequent search stage (Perkins and Roberts, 2002) can include revisiting locations that have previously been attended in more detail and consequently the degree of assurance given to the second phase is significantly higher than that of the former. Phase two can last for many days, weeks or months and the search plan will adapt as time passes or additional information comes to light. Each of these operational phases are approached differently concerning the search and investigation and consequently, the identification and prioritisation of high probability areas and type of search resources allocated to these will alter accordingly (Perkins and Roberts, 2002).

In this paper, we confine our attention to these first two stages, the initial phase, the period of up to 24 h after submersion and the subsequent phase, the time following this. The examination of the initial phase concerned both field data analysis and laboratory experimentation. Variables associated with the subsequent phase were examined using field data.

Methodology

The research was conducted in two parts, with the results of the first data collection informing the subsequent experimentation. Initial data was collected in the 'Body Recovery From Water Study' which comprises a questionnaire that is designed for completion by a diverse range of search and recovery operatives, these include professional practitioners and volunteers based both in the UK and international geographical locations. It is intended for use concerning bodies that have been recovered from inland waterways, or marine environments within 50 m proximity to land. The questionnaire, (which can be viewed at www.bodywaterstudy.co.uk) gathers field data specifically for the study which is analysed and utilised to inform the supplementary laboratory experiments.

The questions are open ended and are grouped into three key areas; (i) the circumstances of how and why the body entered the water and its recovery, (ii) variables relating to the water environment, and (iii) details describing the body. The questionnaire was designed with specific hypotheses in mind which were formed based on what had been seen as possible relevant factors whilst working as a practitioner in the field. The variables included: (i) types and amounts of clothing and footwear, (ii) age and gender of the subject, (iii) temperature and depth of the water, (iv) decomposition and post-mortem submersion interval (length of time in the water).

Information relating to a body recovery is supplied by practitioners completing the questionnaire and it is sent via email or by an alternative electronic method. The data collected relates to inland body recoveries or those in a marine setting within 50 m of land, however, the findings from the research can be applied to assess body buoyancy and movement in both inland or in marine environments.

The data from questionnaire returns were entered verbatim and chronologically (according to when the questionnaire was received) into a database and additional fields are added to categorise the data for analysis. The preparation of the field data was approached on the basis that the movement of the bodies in both the initial (first 24 h) and subsequent time periods (more than one day) should be examined independently. It is important to differentiate between initial movement associated with the body, clothing and water variables and later movement that might have been affected by decomposition given that the gases created during the decomposition process may influence the movement of the body. This approach of separating cases where decomposition may become an influencing variable obtained the best possible potential from the data and followed the phases of a practical search operation.

The data collated from the first 280 submitted cases were statistically analysed to identify relationships between variables. A predictive model was also created to establish the percentage probability of buoyancy of the subject dependent on a range of identified factors. The sample was made up of cases involving 237 male victims and 43 female victims with an age range between 4 and 90 years of age. 44.29% of the sample were identified as accidental incidents, 34.29% of cases list suicide as the causal factor for death, in 19.29% of the cases the cause of death was unknown or could not be verified, 1.79% were deposition recoveries and a single case (0.36%) was classed as 'other' category where a victim was murdered by drowning. The results of the analysis of this data indicated that there were a number of variables that influenced body buoyancy (see below in Section 4), and two of these variables from the initial phase, clothing and footwear were selected for further examination in a controlled environment of a water tank in the fluid mechanics laboratory of the University of Dundee, UK. A model was constructed to replicate a human body, which was dressed in varying combinations of footwear and clothing, and its buoyancy was assessed by quantifying the amount of weight required to submerge the model. The clothing categories included; no clothing, light clothing (cotton shorts and a t-shirt), medium clothing (light clothing and trousers a shirt and a hooded top) and heavy clothing (medium clothing with a winter coat) and the footwear categories were; no footwear, boots, shoes and trainers. In total, 16 different clothing and footwear combinations were considered (see Table 1).

The field data was used to select the sizes and types of some of the clothing items used in the experiment. For example, the size 'medium' was selected (46.43% of the sample were classed as a medium sized adult) and jeans were chosen as the trouser type (40% of the field data sample were listed as wearing jeans on recovery).

Table 1: Combination of footwear and clothing scenarios considered in the laboratory experiments

Footwear	Clothing category	Clothing description
None	None	N/A
None	Light	Boxer Shorts, T-Shirt
None	Medium	Boxer Shorts, T-Shirt, Shirt, Hoody, Jeans,
None	Heavy	Boxer Shorts, T-Shirt, Shirt, Hoody, Jeans, Winter Coat
Boots	None	N/A
Boots	Light	Boxer Shorts, T-Shirt
Boots	Medium	Boxer Shorts, T-Shirt, Shirt, Hoody, Jeans,
Boots	Heavy	Boxer Shorts, T-Shirt, Shirt, Hoody, Jeans, Winter Coat
Shoes	None	N/A
Shoes	Light	Boxer Shorts, T-Shirt
Shoes	Medium	Boxer Shorts, T-Shirt, Shirt, Hoody, Jeans,
Shoes	Heavy	Boxer Shorts, T-Shirt, Shirt, Hoody, Jeans, Winter Coat
Trainers	None	N/A
Trainers	Light	Boxer Shorts, T-Shirt
Trainers	Medium	Boxer Shorts, T-Shirt, Shirt, Hoody, Jeans,
Trainers	Heavy	Boxer Shorts, T-Shirt, Shirt, Hoody, Jeans, Winter Coat

Results and discussion

The data from the 'Body Recovery From Water Study' confirmed hypotheses that had been formed whilst working as a practitioner: In the initial phase; the older in age the person was prior to death, the more buoyant the body (as a general rule) and accidental deaths were less buoyant than suicidal ones. There was no correlation with advanced age and body mass, indicating that the increase in buoyancy in age could be due to reduced bone density, reduced muscle mass, clothing, and footwear. Generally, more of the accidental cases where the body was less clothed (e.g. swimming accidents) were younger people and the smaller sample of older age accidental cases were more heavily clothed. Conversely, while some suicide cases removed their clothing prior to entry into the water, this did not always occur, so deaths in water by suicide were dressed in more clothing layers than accidental cases. Analysis of the data allowed the creation of statistical models of prediction for this phase based on the field data and the experimentation, an example of which can be seen in Fig. 1.

This line graph illustrates the percentage probability of buoyancy for a male corpse depending on the manner of death and age. It shows that the body will be less buoyant if the circumstances relate to an accident rather than a suicide and that in general buoyancy increases with age in both accidental and suicidal cases albeit at a different rate.

The laboratory work corroborated the field data trends from the initial phase. Buoyancy of the model increased with the amount of clothing. For light, medium, and heavy clothing, the percentage increase in weight required with each additional clothing category was 50%, 300% and 766% (Table 2).

Evidence was recorded of pockets of air forming in clothing and remaining uppermost until escaping and dissipating on the surface of the water. This suggested that additional weight was required because air was trapped between the layers of clothing. This added buoyancy until the air was released during the submersion process.

Buoyancy was also affected by footwear, the absence of footwear or the wearing of boots seemed to reduce buoyancy and trainers and shoes added to the buoyancy in the field data. The laboratory results corroborated the field data in all categories except for the boots category which were the second most buoyant footwear after trainers.

In the subsequent phase (the period after 24 h) the buoyancy of the bodies in the field data sample increased with time in the water and there was a correlation between positive buoyancy and an

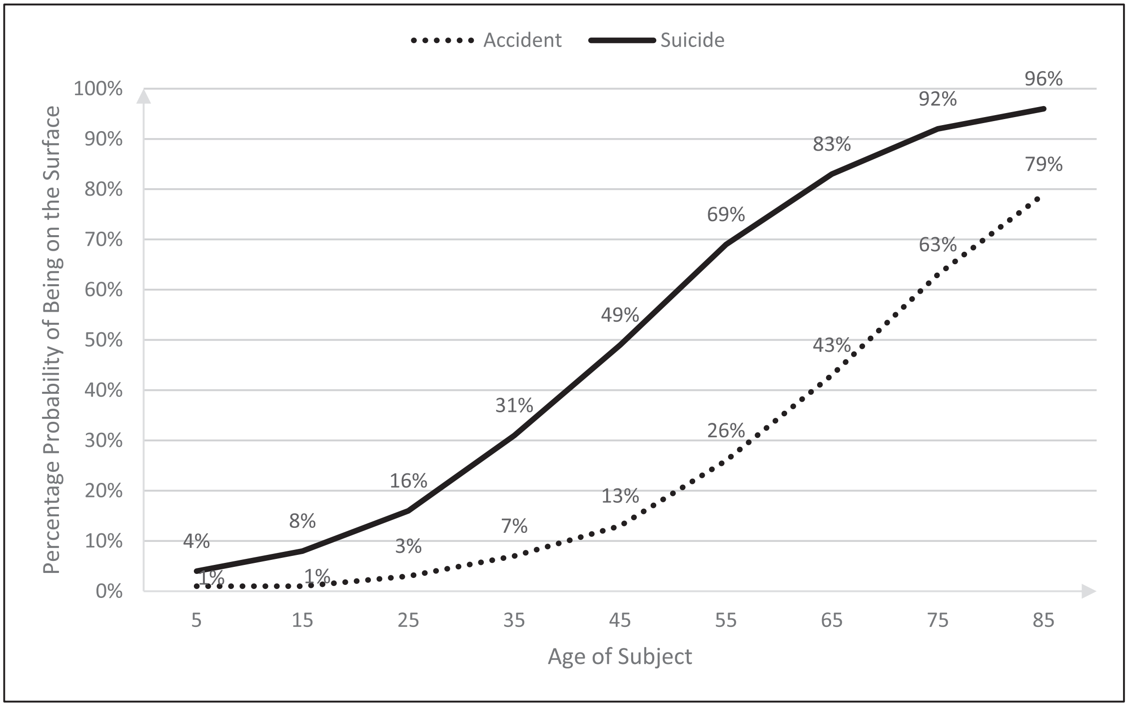

Figure 1: Line graph representing a model of prediction for buoyancy by age and reason for presence in the water (n = 74)

Table 2: Increase in weight added to submerge model and percentage likelihood of positive buoyancy changes for no footwear and all clothing categories

Foot-wear	Cloth-ing	No. of tests	Mean weight of articles worn (g)	Experiment results: weight added to submerge model				
				Mean (g)	Increase from baseline (g)	Differ-ence (g)	Increase from baseline (%)	Difference (%)
None	None	6	N/A	394.08	N/A	Baseline	N/A	Baseline
None	Light	6	189.67	593.42	199.34	199.34	50.58%	50.58%
None	Medium	6	1702.55	1579.43	1185.35	986.01	300.79%	250.21%
None	Heavy	6	2448.80	3414.97	3020.89	1835.54	766.56%	465.77%

increase in water temperature. There was also a correlation with post-mortem submersion interval (time in the water) and decomposition. The range of time at which the body could refloat was measurable and it was possible to make a basic model of prediction which showed the percentage of cases which would be more likely to be on the surface over time (Table 3).

The model of prediction in this phase was based on the post-mortem submersion interval and body buoyancy. Additional data analyses incorporated water temperature and suggested a trend with warmer water temperatures and an increase in body buoyancy.

This research proposes that, theoretically, the movement of a positively buoyant body (which is not physically restricted in any way) will be influenced by the environment, for example, the dynamics of the water, or, if the body is on the surface and there is no water flow, it may be carried by the wind or other factors. A negatively buoyant body can also be moved by water currents or flow

Table 3: Percentage probabilities of body being subsurface as post-mortem submersion interval increases in days (n = 77)

Number of days	Probability of being subsurface (%)
2	66
3	64
4	61
5	59
6	57
7	54
8	52
9	50
10	47
15	35
20	25
25	17
30	11
35	7
40	5
45	3

but it will experience friction with the bottom of the water course and contact with obstructions and this may slow or hinder movement. If the missing person is not located in the initial phase, the search advisor will want to know if that body will 'refloat' and what the time frame for this is. Search activity, selection of assets and prioritisation of geographical areas will be decided with this in mind. In the event that a body is not found during the 'refloat' window, it may travel and eventually submerge which will reduce the chances of discovery through search processes.

As stated above, the findings of this study are designed to be used by search practitioners with existing knowledge and experience in search planning and implementation. It is reasonable to state that findings from research studies should not be offered as a replication of what will happen in the field, however, it is possible to use the results as a basis upon which to build a response to an incident. In this case the authors propose that the results of this work can be used as a starting point when undertaking search planning, the practitioner can apply this knowledge to their hypotheses, the circumstances and the geographical place of the search. The results from this research project and those of continuing analyses of the growing dataset and experimentation will be made available to practitioners though a software application which is currently under development. This will be a user-friendly and regularly updated 'tool' available at no cost to search operatives and investigation teams to achieve search objectives. Initially, suggestions will be presented as a dichotomous choice of buoyancy; 'on the surface' or 'subsurface'—on a scale from 'extremely unlikely' to 'extremely likely'. These predictions will then be supplemented with 'tell me why?' information through which the basis of the analysis can be shared, possible limitations can be raised and guidance given for consideration. This will allow the user to make an informed decision with all information possible and the academic research being presented in the most user-friendly, meaningful and lowest risk way. The application is being designed to be used alongside existing knowledge and experience and can be interrogated at any given point during a search investigation to assist with prioritisation of search areas and guidance on suitable assets for deployment.

Concluding remarks

The benefits of the use of scientific research by police practitioners are abundant and have historically been demonstrated in a range of criminological areas, including offender profiling, behavioural science and crime data analyses. The field of search, rescue, and recovery has benefitted from behavioural science research aimed at predicting the likely movement of missing people on land but research like this, based on the natural sciences has not been prevalent.

The approach of the Body Recovery From Water Study proposes that every search practitioner investigating a missing person case is a researcher, making deductions and decisions and using a range of information at their disposal. This should be a core function of an inquisitive practitioner. The operative (as a service deliverer) also needs to be linked to the analysis of the data and deliverers and thinkers should be the same body. Useful data and potential for learning and development is lost because the deliverer doesn't see themselves as a feedback giver, or a person invested in the process of research. This study demonstrates that it is possible to gather relevant data and interpret it in a way that it can begin to be of use to those working in the field of search and recovery.

The Body Recovery From Water Study is an innovative example of how police (and other agency) practitioners can use scientific systematic approaches to improve the craft of missing person search and investigation. This research is already in use to inform search strategies where a person is thought to be missing in water, the author utilises it for her own practitioner searches in her capacity as a police search advisor and supports other UK search personnel with advice for outstanding missing person cases. It is clear that the trends emerging from this work enable a practitioner to apply some rationale to decision making and this study highlights the potential benefits for the continuation of this project and similar approaches across the policing spectrum.

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