

THE PREDICTION OF SURVIVAL TIME IN WATER

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INTRODUCTION

Work has been conducted for over 50 years with the aim of estimating the survival time of individuals accidentally immersed in water. This work has included the mathematical modelling of responses obtained from laboratory experiments and accidental immersions. The difficulty of producing an accurate prediction, given the range of environmental conditions and factors that can influence survival time, is reflected in the statement in a UK Health & Safety Report in 1996 that, “there is still a need to define a realistic estimate of probable survival times for people immersed in the North Sea” (Robertson & Simpson, 1995).

The US Coast Guard (USCG) Research and Development Centre (R&DC) was tasked by the USCG Office of Search and Rescue (CG-534) to facilitating new approaches that would improve the quality of the existing survival prediction capability (Turner et al, 2009). This involved reviewing the results of laboratory studies and accidents that related to survival in water. A few relevant studies in this field include those by Molnar (1946), Keatinge (1969), Hayward (1975), Golden (1976), Nunnely and Wissler (1980), Allan (1983), Lee and Lee (1989) and Oakley and Pethybridge (1997). The classic study of Molnar (1945) involved plotting a scatter graph of recorded immersion times of US Navy shipwreck survivors and the respective water temperatures between April 1942 and 9th April 1945. Molnar drew a curve above the plotted points. This curve “*represents a limit of tolerance that few men can exceed and many cannot approach*”.

With regard to current advice for search and rescue organisations, it is accepted that predicting survival time is not an exact science. To cover themselves, SAR co-ordinators must extend the search times beyond that which they can “reasonably expect” anyone to survive. As a general rule it is considered prudent for the recommended search times to be in the region of at least 3-6 times the predicted 50% survival times (Golden & Tipton, 2002). Currently the US Coast Guard has a survival prediction model in place called the Cold Exposure Survival Model (CESM). Feedback from the operational users has indicated that there are not enough cases below 15°C in the CESM data set; the upper prediction times are limited to 36 hours, leaving the controller to add varying ‘safety margins’ to the given survival time predictions.

The USCG identified the UK National Immersion Incident Survey (UKNIIS) as the largest cold water data set worldwide. The survey collects information about the physical attributes of the immersion victim (e.g. sex), the surrounding conditions (e.g. water temperature) and the rescue (e.g. the duration of immersion before the rescue of the victim). The Institute of Naval Medicine

are the custodians of the survey and the data were last reported upon in 1997 (Oakley & Pethybridge, 1997). Since 1997 the UKNIIS has been extended by continuing data collection. The aim of the current project was to update the UKNIIS and see if could provide a more definitive prediction of maximum survival time in cold water.

METHODS

The data (up to 1997; 993 cases) were coded and entered on an Excel spreadsheet. An additional 600 subsequent cases were in paper form and transferred onto the same spreadsheet. The whole spreadsheet was given a new coding format. The complete UKNIIS was analysed to find firstly, the most significant factors involved in cold water immersion survivability, and secondly, develop a model to predict the median survival time in cold water, using the most significant variables. ‘Median survival time’ was defined as the time that 50% of people would be expected to survive.

RESULTS

The five most significant variables for predicting survival time were found to be: age of victim; clothing of victim at time of accident; whether a personal flotation device (PFD/Lifejacket) was worn; water temperature; and water area (i.e. inland, coastal, inshore and offshore). The Weibull exponential distribution was used to develop the survival time predictions. There are thirty one permutations of the five variables, for this reason thirty one equations were developed. The single variable equations are:

- Water temperature;
 $t = 2.23e^{0.1099*WaterTemp}$
- Age;
 $t = 20.06e^{-0.04*Age}$
- Water area;
 $t = 2.44e^{0*x_1+0.56*x_2+1.44*x_3+0.37*x_4}$
where $x_1 - x_4$ are the different categories of water area, listed above
- Clothing;
 $t = 54.08e^{0*x_1-0.14*x_2-2.78*x_3}$
where $x_1 =$ wetsuit, $x_2 =$ dry suit, and $x_3 =$ other
- PFD;
 $t = 3.63e^{0*x_1+2.09*x_2}$
where $x_1 =$ no PFD worn, and $x_2 =$ PFD worn.

Figure 1 presents the UKNIIS as a scatter plot with those recovered alive and dead identified.

In Figure 2 the longest survival times across the temperature range are joined by a line depicting the “upper observed survival time”.

Figure 3 presents the same plot with the regression line and confidence intervals through the upper observed survival time and the equation for the upper confidence interval which could be used as the “maximum search time” (Max search time = $5.7e^{0.1Temp}$).

Finally, Figure 4 also includes the Molnar and CESM curves.

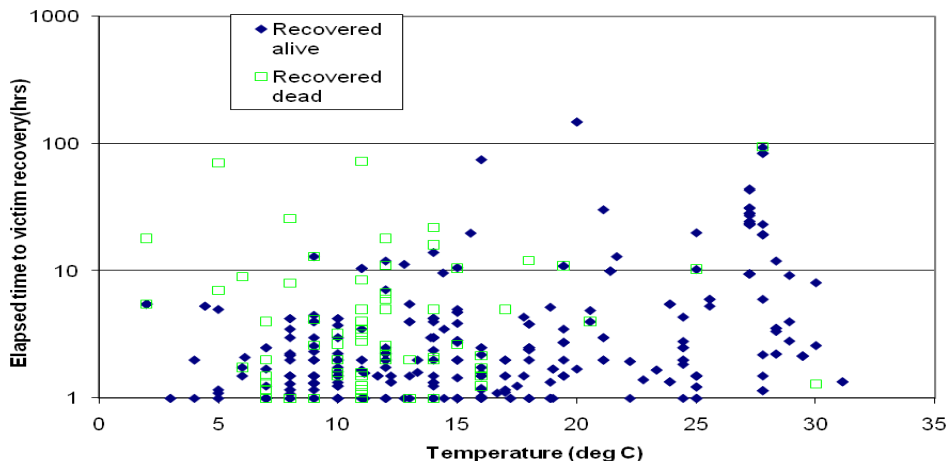


Figure 1. A scatter plot of the cases, with the result for each case differentiated.

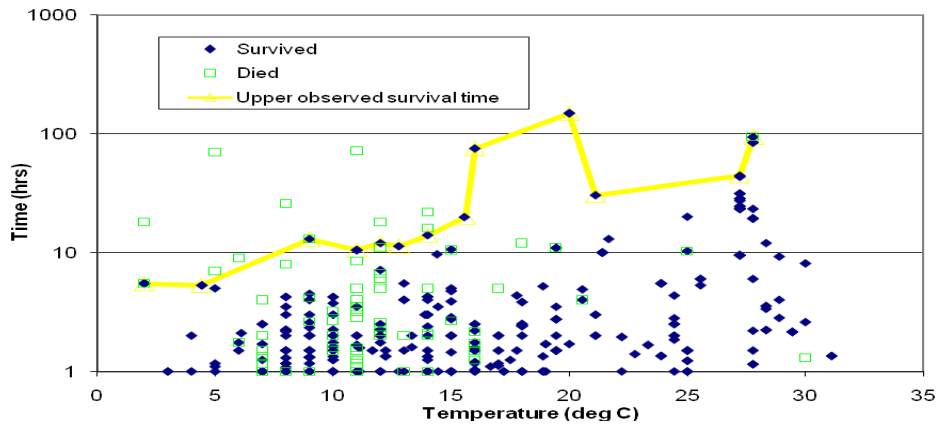


Figure 2. The same plot as Figure 1, with a line through the highest survival times.

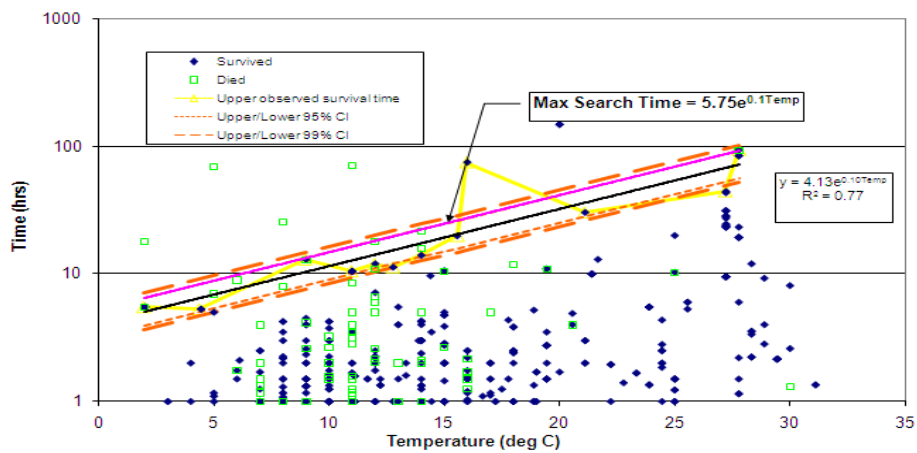


Figure 3. The same plot, with a regression line and upper and lower confidence levels plotted.

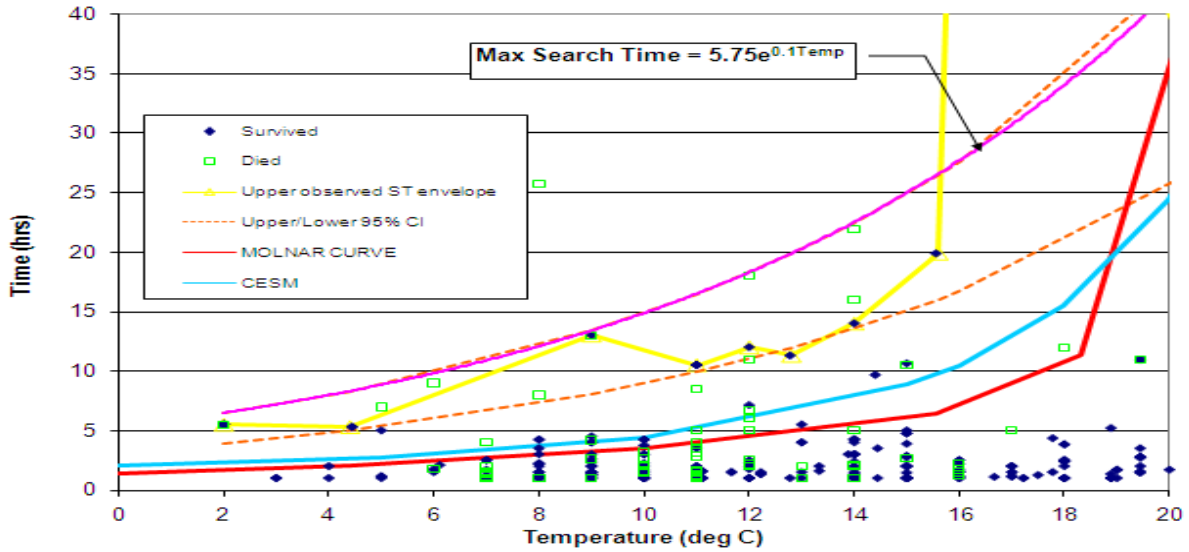


Figure 4. On the same plot, the Molnar and CESM curves have been plotted alongside the UKNIIS data.

Figure 4 shows that the calculated maximum survival time ($5.7e^{0.1Temp}$) is higher than any prediction given before, where survival and consequent search times have been calculated using the CESM model and/or using curves such as that of Molnar with an added ‘safety margin’ of a multiple of the predicted survival time. This maximum search time derived from the present study (Figures 3 & 4) incorporates this safety margin.

CONCLUSIONS

On the basis of the UKNIIS, an equation has been identified for the prediction of maximum survival time ($5.7e^{0.1Temp}$) that appears to embrace the earlier times predicted by both existing models (CESM) and incident-based survival time with an arbitrarily added “safety margin”.

The data obtained from this project will be included in a larger prediction tool being developed by the USCG (Turner et al, 2009).

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