Postmortem submersion intervals in the River Thames

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Abstract

This paper catalogues a dataset drawn from Metropolitan Police records in the period 2004-2015 regarding drowning victims recovered from a tidal stretch of the River Thames and provides a comparative study with a similar dataset from the time period 1956-1959 by the County of London (Western District), H.M. Coroner of that time, Gavin Thurston, from the information gathered in his professional role. In addition to drawing comparisons between these time periods the paper draws inferences regarding the Post-Mortem Submersion Interval (PMSI) and proposing further study required. Both datasets show a significant bias towards male subjects counter to other comparable data in the literature. This bias is even more pronounced in the 2004-2015 period where additionally there are significantly more incidents during Full Moon Lunar Phase. Some weak seasonal trends were observed regarding equinoctial peaks but these were not statistically significant.

There are few clear trends observable in factors that might influence Post-Mortem Submersion Interval although there was a weak and counter-intuitive inverse relationship between clothing weight and time in water.

KEY WORDS: PMSI, Drowning, GIS

Introduction

This paper concerns bodies recovered from the tidal reaches of the River Thames during the period 2004-2015 and in particular their Post-Mortem Submersion Interval (PMSI) (the interval between date of entry and date of recovery). The cases included are those where the known cause of death was by drowning and both the entry and exit points of the bodies were known by the Metropolitan Police's Marine Policing Unit (MPU). We define PMSI in a literal sense, meaning the time spent submerged, and also analyse the distance travelled, but do not consider rates or levels of decomposition.

The key work concerning body recovery from the Thames in London is Thurston (1960), which considered the cases of bodies recovered between 1956-1959 and there has been no work since 1960 concerning the movement of bodies in the Thames. This work uses technology and methods unavailable to previous authors, and addresses a considerable gap in understanding concerning preventable death in a global megacity and European Capital.

The general structure of this paper follows to some extent the format of Thurston 1960 and, where relevant, comparisons are made with these findings. The rationale for this was that the Thurston paper represents the *only* work concerning this aspect of suicide in this major city, and it may be of value to compare results between the two periods, and perhaps determine what factors, if any affect rates and physical geographical characteristics of suicidal drownings in the Thames.

The Thurston paper presents information regarding 82 cases in the period 1956-59, over twice the number of cases in the dataset used in this work. Thurston offered a set of descriptive statistics, illustrated by some case studies, and, where relevant a comparison of the 2004-2015 data is made, and differences are analysed. For the Thurston dataset only secondary data was available and this was not universally applicable to all 82 cases. Therefore, in some circumstances a direct comparison cannot be made, this is discussed in the relevant sections of this paper. The following sections will discuss elements of the river that may have changed (tidal flow, turbidity, development, SAR provision etc) before moving on to the main data analysis of the paper.

Since Thurston's work there has been no published investigation of the patterns and properties of drowned bodies recovered in the Thames in London. The river, its immediate environs and London in general have all changed considerably, as have the organisational structure of the emergency services response on the river. This work will use a dataset compiled by the MPU and a Geographical Information System (GIS) approach to quantify and disseminate the available data on drowning in the tidal Thames. Additionally, this work will seek to provide a baseline set of data concerning the Post-Mortem Submersion Interval (PMSI) of bodies in the Thames, as well as observations on the movement and descriptive statistics of the victims.

The Search and Rescue (SAR) provision on this stretch of the Thames is one of the most drastic changes over the period of this study. The SAR provision was initiated by the 2000 Lord Justice Clarke's Thames Safety Inquiry, in response to the 1989 *Marchioness* disaster on the Thames, in which 51 people lost their lives (Butcher, 2010). The impact of a more efficient rescue system on the river is likely to have had a significant effect upon the death rate of suicide attempts by increasing the number of unsuccessful attempt, and reducing the number of deaths. There had previously been a Marine Accident Investigation Branch report (1991), the Hayes Report (1992) and a Coroner's Inquest (running from 1990-1996). The Inquiry made a number of additional recommendations, amongst which were a consultation on the consumption of alcohol by people in charge of vessels, funding for a formal safety assessment of search-and-rescue facilities on the Thames; and funding for experimental life-saving equipment at locations along the Thames (Butcher, 2010).

As of 2003, Her Majesty's Coastguard (HMCG) began coordination of all Search and Rescue (SAR) activity on the river. Four new Royal National Lifeboat Institution (RNLI) lifeboat stations were established, with three of those four being permanently crewed 24 hours a day, and one relying on a pager system to mobilise locally-based crew members. In addition, the Port of London Authority (PLA) also has Harbour Master and other inspection vessels,and the London Fire Brigade has one permanently afloat fire boat. All of these resources have some SAR capability and can be called upon for search and rescue operations and body recovery. However, the main responsibility for body recovery lies with the MPU and they would be the most likely resource to be mobilised for this operation on the tidal Thames.

Background

River Thames Environment

Below Teddington, the river is tidal, with a large tidal range and strong flows, with the potential to move large objects some distance but is locked and managed above that. There is a lock and weir at Richmond (within the tidal portion of the Thames), which also serves to control the flow and fluvial output into the tidal river. The Thames flood barrier at Greenwich protects London from North Sea storm surges, but also clearly has an impact on the flow of the river. Considering changes since Thurston's analysis, Fig 1 shows a small decline in flow rate, but changes to the nature of the river (a move away from predominantly industrial use) are likely to have had an impact on turbidity and composition of suspended loads further downstream (Werner, 2015).

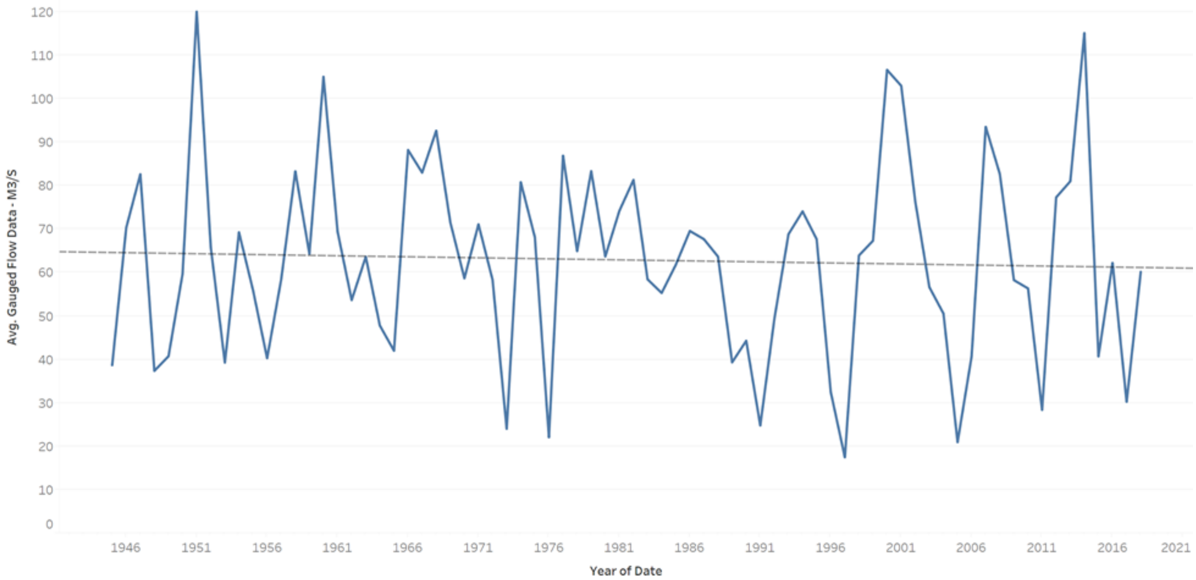

Figure 1: Average Daily Flow (cubic metre per second) from gauged data at Kingston Upon Thames (1945-2018)

The amount of water in the river is related to the rainfall inundating the river's catchment and as such it can be seen that there is a period from October to January where there is typically higher rainfall, more water in the river system and resultant faster fluvial flows (Fig 2). This will be likely to have an impact on the tidal action, on any suspended load, but it is difficult to be specific about the nature or extent of that impact (UK Met. Office, 2020).

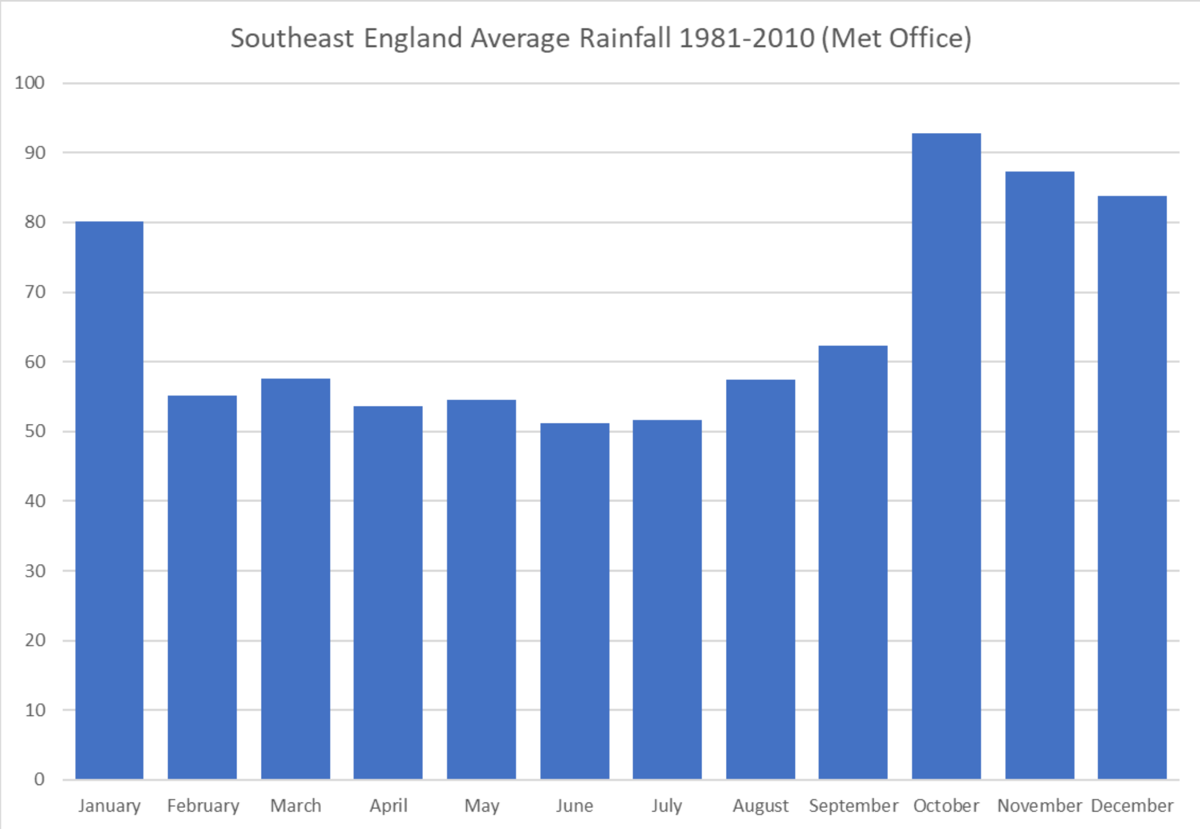

Figure 2: Average Monthly Rainfall (millimetres) for South East England 1981-2010

River Thames: Suicides and Drowning

Drowning itself is a major cause of death, disability, and loss of quality of life and is a leading cause of death among children globally (Branche and van Beeck, 2014). According to Martyn, (2014), there were nearly 400,000 deaths globally in 2004, with over 90% of them occurring in low to middle income countries. The UK, has a relatively low rate of fatal drowning, well under 1 death per 100,000 population (in comparison to Moldava, with 7/100,000) (Saxena *et al.*, 2014) and the highest rate of drowning in swimming pools in the UK is 14-15 year olds during summer months (ROSPA, 2007). Across Europe, suicide by drowning represents less than 5% of all deaths by suicide, with this rate being higher among females (with some countries showing female rates of over 10% suicides by drowning (Varnik *et al.*, 2008)). This may be due to ease of access to water, which of course varies geographically, or as a function of the nature of the suicide attempt. For example, some individuals may select an isolated location, to reduce the likelihood of rescue (and in some cases fill pockets with stones, or bind their hands), some individuals may select a well-populated location, to ensure rescue, where the intention is to attract attention, but not actually die (Lunetta and Connolly, 2014).

Concerning suicidal drowning in general, Copeland (1987) provided an analysis of both location, demography and rationale, determining that canals or the home were the most frequent locations (both 21.4%). The study determined that the population predominantly consisted of older white males, and was typically as a result of some depression concerning a variety of factors (Copeland, 1987).

Byard et al (2001) carried out a retrospective analysis of South Australian suicides by drowning, looking at 176 cases that dated from 1980 to 2000, although only 29 of these related to those who drowned on a waterway (as opposed to a bath, swimming pool etc). There were 76 males and 47 females, with a total age range of 16 to 88 years. Female victims tended to be older than male victims, and victims were more likely to be suffering from mental illness than from a physical illness.

There are fifteen bridges over the Thames in central London, and whilst being of great utility to the city, and in some cases serving as tourist attractions in their own right, they have sadly and inevitably been used by those seeking to take their own, or others' lives. There are parapets and railings along all of the bridges, but the requirement for them to afford views of the river and the city mean that they are not impassable. In the last 50 years the river has been cleared of industrial buildings considerably along its banks with both north and south banks offering access to the river along almost all of their length (Haywood, 1998; Ward and Robinson, 2000). The HMCG control centre is based at Greenwich, but has live links to CCTV cameras on the majority of bridges over the Thames, as well as other sections of the river bank. London also has a plethora of "passive" cameras around the Thames, which could be accessed for forensic investigation after an event (Skogan, 2019).

The fluvial flow of the Thames does have some seasonal variations (above), and there is some evidence for seasonality of affective disorders, with Lukmanji et al. (2019) finding a significant seasonal variation, amongst certain age groups, of feelings of depression or low self-worth. However, this same study found that despite this, there was no increase in suicidality in any season. Rotton and Kelly, (1985) and Greatbatch et al. (2019) also found no statistical increase in incidents for the emergency services, psychiatric admissions, homicide, disasters or suicide during full moon periods.

Newiss and Greatbatch, (2019) found a significant number of men missing from a night out were found dead in water, although none of these were suspected of being suicides. Partonen et al. (2004) found that suicides in Finland were not evenly distributed across seasons, were higher around the phases of a new or full moon, and attributed this mismatch to changes in ambient temperature and light. Lasota et al. (2019) found a spring peak of suicides was for men, and an autumn peak for women, and Aguglia et al. (2019) found that high-lethality suicide attempts were significantly greater than low-lethality attempts during the months with most sunlight (June and July). In conclusion, the literature does not provide a conclusive answer as to the likelihood of a seasonal affect in suicide by drowning in the Thames.

Post-Mortem Submersion Interval

Detailed research into the precise mechanics and movement in water of the human body is however difficult to carry out. This is due in part to the unpredictable nature of drowning incidents, along with the likelihood of recovery by the authorities as soon as a body is discovered. It is also impractical and unethical to carry out experiments with trackers on either dummies or cadavers, for fear of upsetting the local population. In this sense, water based forensic experimentation is at a disadvantage to terrestrial research, where body farms can be used to test factors and circumstances in distribution of bodies by scavengers and general decomposition (Williams *et al.*, 2019).

There is limited research on the level of clothing remaining on drowned victims, but Helmus et al. (2018) found with experiments on cadavers in private rivers that it was common for bodies to remain at least partially clothed after immersion, although the focus of their study was focused on the persistence of DNA on clothing. Dennison-Wilkins (2021) found that questionnaire returns from recovery teams suggested that differences in buoyancy relating to clothing and footwear existed. The differences were related to the amount of clothing remaining or initially present on the body and the type and construction of clothing. They also found that buoyancy appears to increase with age of the individual and that the manner of death itself has an impact on buoyancy, which logically then impacts upon PMSI.

According to Haw and Hawton (2016), most bodies drowned as a result of suicide were found wearing outdoor clothing, with a smaller group in nightwear, swimwear or naked. Lunetta et al. (2014) note that post-mortem identification of bodies is often difficult as “clothing and other personal effects are lost in water”. Armstrong and Erskine, (2011) note that nude recovered bodies may be as the result of the “stripping off of clothing caused by rough water conditions or snagging against underwater debris versus a dumped body with death by other means”. It therefore may be that clothing is stripped off a body based on a function of flow conditions, river bed roughness, clothing material and length of time submerged. The stretch of the Thames considered in this study is not uniform in terms of flow, tide strength or river bed rugosity. However, it is certainly true that all of the conditions that may contribute to clothing being stripped post-mortem do exist to some extent in all reaches.

The length of time that bodies spend underwater, once submerged, is of importance to later investigations, and determining the events leading up to death, especially so in any criminal investigation. As a result, there have been a number of attempts to generate heuristics that relate the state of decay of a body to submersion interval, and other environmental factors, either using animals as human analogues (Humphreys *et al.*, 2013), or through data analysis from fatality databases. van Daalen et al. (2017) used the date a victim went missing as a start or immersion date, and used that (with recovery date) to estimate PMSI and investigate levels of association between PMSI and decomposition. The mean PMSI was 41 days, based on 38 cases of bodies recovered from the North Sea by the Dutch Department of Missing Persons in the North Sea (BVPN).

The movement of drowned bodies through water, and the various related characteristics of that movement are also of interest to forensic investigators, leading potentially to the identification of missing people or leading searchers to locate drowned victims faster and more efficiently (Byard, 2018; Mateus *et al.*, 2013; Reijnen *et al.*, 2018)

Clearly, functions of water movement, through currents or flows and a body's specific gravity (SG) (combining physical characteristics, levels of gas within the body and additional items such as clothing) determine how fast, in what direction and at what depth a body is suspended. With a specific gravity less than 1.000, a body will sink in fresh water and remain there until gases within the body are produced as a result of decomposition, bloating occurs and the SG is raised (Lucas *et al.*, 2002). Water temperature, body fat, river microbial activity, weight of clothing and the roughness of the river bed are all factors in any post-mortem movement, as they affect the speed and level of bloating, as well as the forces acting upon the body resulting in movement, and as previously started, all of the environmental conditions impacting body movement are present within the tidal and non-tidal reaches of the Thames in London.

Recent research into PMSI in the UK has been focused within the forensic science field, and the prediction of PMSI from post-mortem injuries on bodies recovered. Heaton et al. (2010) found that a combination of submersion and temperature had a measurable and predictable impact on the level of decay to the body, and as a result made some progress towards being able to predict the duration of submersion from the level of decay (ibid). They reviewed 18 cases from the Rivers Clyde and Mersey in the UK, and had access to closed case files, autopsy results and crime scene reports to determine the level of decomposition.

Method

The data regarding the drowned victims was provided under license from the National Crime Agency, the National Missing Persons Bureau and from the Metropolitan Police, although the data was specifically sourced by the MPU. The criteria for records to be forwarded were that both the recovery location *and* point of entry were known. There are records kept by both the RNLI locally, and the police, of all bodies recovered, which on average numbers between 20 and 30 a year. Records where both entry and recovery are known are, understandably, fewer in number, as it is rarer for someone to be observed entering the water and not be rescued immediately. Some of these records overlap with the dataset used in this study, but there is no requirement for harmonised recovery records. The contemporary dataset will be referred to at the Met. Police 2004-15 dataset in this work.

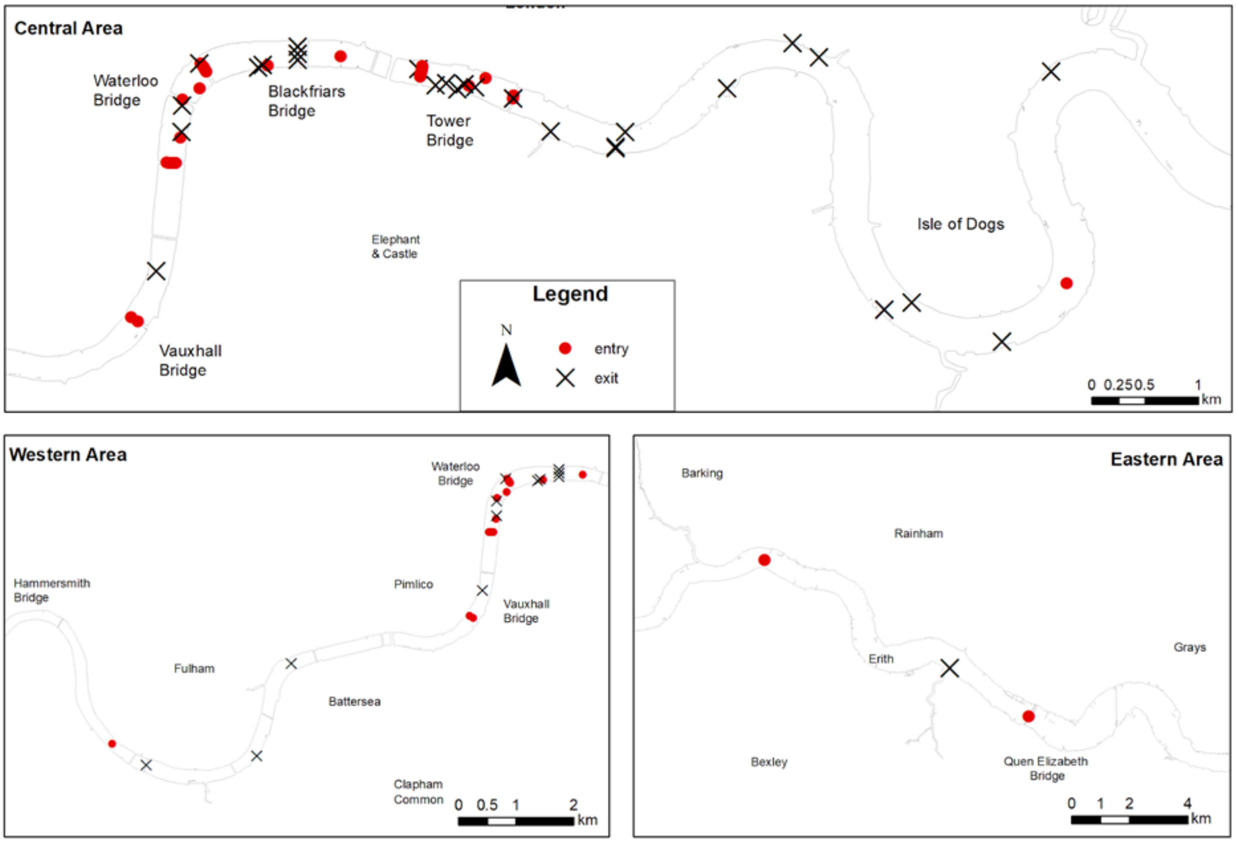

Figure 3: Entry and Exit Locations of Drowned Bodies (June 2004-May 2015) from Metropolitan Police Records

The data contained 33 records of drownings in total for the period covering June 2004 to May 2015, the distribution of which are shown in Figure 3. The dataset contained the sex, age and clothing of the casualty when recovered, as well as the date and location of both entry and recovery. All cases were all believed to be suicides (apart from 1 case, which was accidental), and all but one casualty was male.

Standard data processing allowed additional data to be incorporated to the dataset, such as phases of the moon, and PMSI (in days). In addition, the level of clothing remaining on each recovered victim was quantified using a simple grading system as shown in TABLE 1. The number of items of clothing was added as an integer to the database to allow descriptive statistics and comparisons to be produced.

Clothing Level	Score
Naked, or near naked	1
Clothing but no shoes	2
Clothing and shoes or trainers	3
Clothing and heavy boots, or heavy overcoat	4

Table 1: Coding for clothing levels.

The entry and recovery points were digitised in ESRI ArcMap 10.2.2 to as close a position as could be determined from the description (Fig. 3), although some uncertainty will be present in the data as a result of there being no record of where exactly from a bridge or jetty a person jumped, nor where precisely they were recovered. The description of recovery tends to be a guideline location on the river, denoted by a local landmark (such as Chelsea Harbour Pier) which allows for a point to be placed in space in order to carry out analysis, but is inherently uncertain.

The points were then joined by lines that ran along the centre line of the river (having no other information as to their true track) and these were snapped to the centre line (rather than using a straight line that would have cut across the *meanders* of the Thames) using a form of *Dynamic Segmentation* (Chiou *et al.*, 2010) and the distance along the river from entry to recovery points was calculated.

Results

The key text concerning drowned body recovery in London is Thurston's 1960 paper, which considered cases of bodies recovered from the Thames between 1956-1959. There were 66 body recovery cases in that period. In 12 cases where the victim was seen to enter the water, however in 21 additional cases corroborative evidence for entry point was available such as recovered personal belongings or discarded clothing. This resulted in 33 of the 66 cases available to Thurston, having known entry and exit points. Nearly all cases were considered suicides even though 65% of them had open verdicts. The proportion of drowning cases in general, and suicide cases in particular available to Thurston as Chief Coroner of the County of London (Western District) are likely to be greater than the proportion of those available to the Metropolitan Police for the reporting period covered in this paper and so it is not possible to infer anything about the rate of suicide by drowning by comparison of the numbers recorded during the respective periods.

What follows are a set of comparative descriptive statistics between the Metropolitan Police cases (2004-15) and Thurston's cases (1956-59) following the format adopted by Thurston, and illustrated by some case studies. The geographical area for the 1956-59 Thurston cases coincides with those entry and exit points falling entirely within the Western Area of the Metropolitan Police cases 2004-2015 (Fig 3), and these number a total of 12 out of the 33 cases. The statistics are further subdivided according to the Western Area to allow direct comparison with the Thurston cases. Where relevant the Metropolitan Police dataset is split into geographical regions, for example comparative drift distance which is likely to be influenced by the flow regime.

Drift Distance

	Met. Police 2004-2015 All Cases	Met. Police 2004-2015 Western Area Cases	Thurston 1956-59 All Cases
under 1/4 mile (0.4km)	6	3	20
1/4 to 1/2 mile (0.4 - 0.8km)	4	3	5
1/2 to 5 miles (0.8 - 8 km)	21	6	5
5 miles (8.0 km)	0	0	1
6 miles (9.7km)	1	0	1
7 miles and over (>11.3km)	1	0	1
	33	12	33

Table 2: Drift distance of bodies recovered in the two datasets

Table 2 shows the drift distance of the recovered bodies following the format and data bins adopted by Thurston (1). The notable differences are that for the 1956-59 cases:

'Mostly, the bodies were found very near to the point where they entered the water' (p 196), with 20 out of 33 cases (61%) found within 0.4 km as opposed to 3 out of 12 cases (25%) for 2004-2015. In the present study 6 out of 12 cases (50%) were found between 0.8 and 8 km away against 5 out of 20 cases (25%) in 1956-59.

There were 3 out of 33 (9%) of subjects found at 5,6 and 7 miles that were categorised as having all entered the water above Richmond (1), and there were no similar cases in 2004-2015.

No instances of long-travelled cases over 5 miles (around 8 km) were recorded in the Western Area in the present study. A possible reason is that there were no cases of bodies being recovered in the MPU dataset with both entry and exit points above Richmond rather than a fundamental change to the flow regime or other external factors. Therefore no direct comparison can be made for this reach.

Whilst the “Western Area” corresponds most closely to the area covered by Thurston’s study, the number of cases for 2004-15 for this area alone is insufficient for detailed statistical analysis. However, the total number of cases in the present study is identical to that for the period included in Thurston (1956-59). By grouping both datasets into just three distance categories (< 0.5 miles, 0.5 - 5 miles and > 5 miles), it was possible to compare the distributions of drift distances for the two datasets using a χ^2 test, indicating a very highly significant difference in distribution ($\chi^2 = 16.47$, df = 2, $p < 0.0003$). The modal drift distance category for the Thurston data was for bodies which had drifted less than 0.25 mile, whilst for the 2004-15 data, the modal group was for drift distances between 0.5 and 5 miles. However, the numbers of bodies found having undergone very large drift distances (> 5 miles) were very similar for both datasets (Table 2). This implies that on average, excluding the longer drift distances, drift distances have increased since Thurston’s paper. However, since Thurston’s data is only available in grouped form, it is not possible to perform a more quantitative statistical test (such as a t-test or Mann-Whitney test) on the two sets of drift distances.

Factors that may have contributed to the observed changes in intervening times include: flow-regimes in the Thames, predominant clothing fashions and fabrics, and changes to likely time to discovery. Table 3 gives a qualitative analysis of the expected influence of trends on factors responsible for body drift. The apparent decrease in the proportion of bodies found close to their entry points implies that the post-1960 changes should indicate qualitative factors with an increasing expected influence on typical drift distances, however, the opposite effect is observed in the drowning statistics presented in this paper.

Drift Factor	Change from 1960s	Expected Influence on Body Drift
Flow Regime	Decline in peak flood events (3) Non-significant annual mean flow at Kingston Gauging Station (1945-2018)	Negative No change
Clothing	Lighter Modern Fabrics (35, pp.21-43, 36 pp.948-956)	Negative
Time to Discovery	Increased monitoring of River reaches (6)	Negative
Tidal Flows	Thames Barrier (1982) Sea level rise	Only during extreme events such as exceptional high tides or storm surges Increased frequency of exceptional events (Haigh et al 2016). Possibly ameliorated by Thames Barrier

Table 3 - Qualitative analysis of changes to factors influencing drift distance since the 1960s

Thurston attributes the reason for long travelled upstream cases being a less-marked tidal effect in the higher reaches where downward river flow predominates ‘enhanced by periodic opening of sluice gates’ a practice that still occurs for about 2 hours either side of high water. There was a major refurbishment of the Richmond Lock and Weir in the early 1990s which may have affected the flow regime (Port of London Authority, 2020)

Sex

Of the 82 cases recorded in Thurston's paper there was less than one female case to three male cases, which contrasted with the overall suicide case data in England and Wales (1956-59) of two female to three male suicides (1). Table 4. Shows the comparative break-down of the cases by sex between two datasets, the MPU data showing an even lower female to male ratio of one to thirty-two.

	2004-2015 All Cases	**Thurston Cases**
Male	32 [97%]	64 [78%]
Female	1 [3%]	18 [22%]
	33	**82**

Table 4: Sex of bodies recovered in the two datasets

Data is available from the UK Office for National Statistics (ONS) on numbers, by sex, for both all suicides in the UK, and for suicides by drowning in the UK, year by year (Office for National Statistics. Statistical Bulletin:, 2017). Comparison of both the Thurston and the Met. se) Police 2004-15 data with the ONS data for 2016 indicate significant differences ($p < 0.02$) in each case between the sex ratios for each of the two datasets, using either a χ^2 test or an "exact" test based on a binomial distribution. A particularly high significance was obtained, as expected from visual inspection of the datasets, between the sex ratios for the Thurston and the Met. Police 2004-15 data ($p < 0.003$), indicating that the observed differences in male/female suicide rates between these two studies is not due to chance.

Both Thurston's dataset and the Met. Police 2004-15 dataset indicate a significant bias towards male subjects as victims of suicides by drowning in the Thames which is in marked contrast to the European data regarding deaths by drowning attributable to suicide (Lunetta and Connolly, 2014). This male-female sex bias increases significantly between the 1950s and 1960s and the 2000s where in the latter only 1 of the 33 cases is female.

Seasonality & Phases of the Moon

One of the patterns observed by Thurston was that there was an “increase in drownings in early autumn” (1 p197) (Fig 4). Partonen et. al. (2004) observed seasonality influences on Finnish suicides which were potentially attributable to changes in luminance and temperature, that could affect intrinsic time-keeping mechanisms that influence individual body-clocks. The comparative seasonality of the drowning cases between the Thurston and contemporary dataset is shown by month (Table 5a) and by meteorological season (Table 5b). In contrast to the Thurston data, the Met. Police 2004-15 data shows a marked *decrease* during the Winter months with only 2 out of the 33 cases being between December and February.

	Met. Police 2004-2015 (All Cases)	Thurston 1956-59 (All Cases)
January	0	6
February	1	3
March	4	6
April	4	5
May	3	6
June	2	9
July	1	3
August	6	4
September	3	8
October	6	12
November	2	6
December	1	6
Total	**33**	**74**

Table 5a: Variation of bodies recovered in the datasets by month

	Met. Police 2004-2015 All Cases	Thurston 1956-59 All Cases
Spring (March - May)	11	17
Summer (June - August)	9	16
Autumn (Sept - Nov)	11	26
Winter (Dec - Feb)	2	15
Total	33	74

Table 5b: Variation of bodies recovered in the datasets by meteorological season

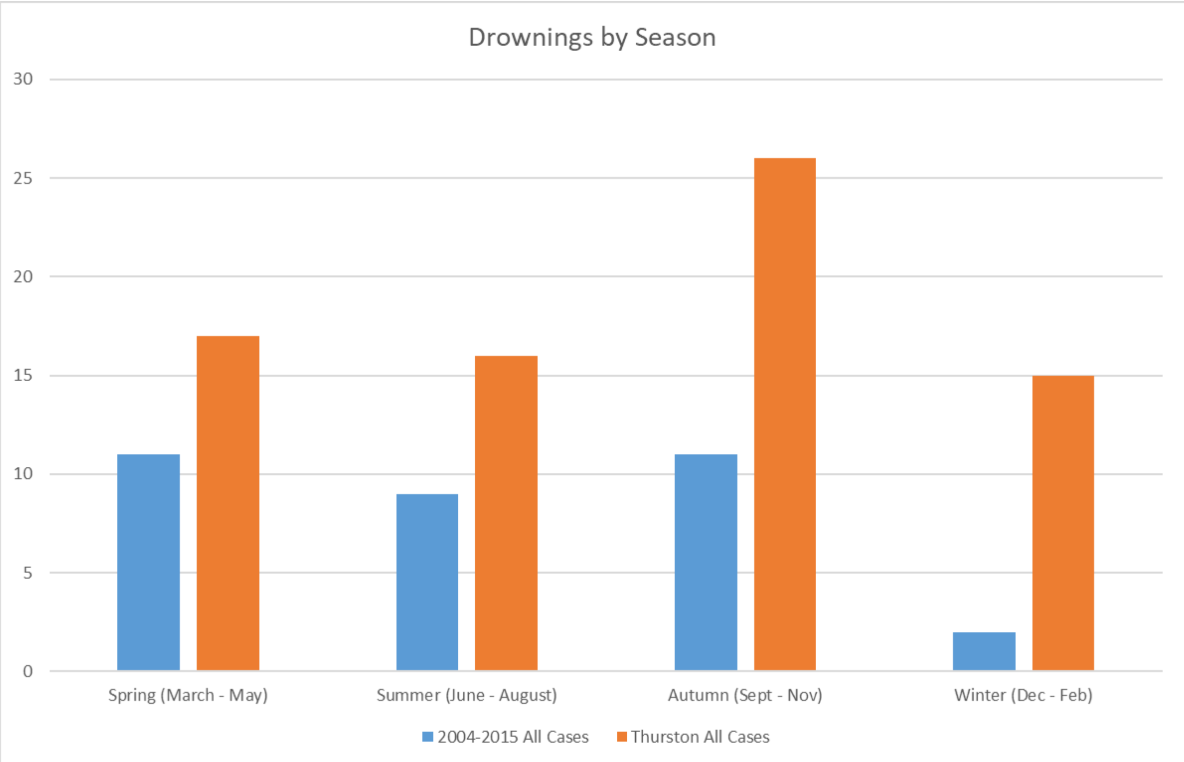

Figure 4: Comparative Seasonal Variations in Reported Drownings: 1956-59 versus 2004-2015

Using the data on the 74 cases for which the month of the case was recorded in Thurston's dataset, and the complete dataset of Met Police 2004-15 cases, a collection of Chi Squared tests on the seasonal data (Meteorological Spring, Summer, Autumn, Winter respectively) were carried out, both within each dataset and between the datasets. None of these proved statistically significant at the 5% level of significance, although in both individual datasets one season did appear to have a very different number of cases (Winter had fewer cases in the Met 2004-15 data, whereas Autumn had more cases for Thurston's data). The test for differences in number of cases between seasons for the Met Police 2004-15 data test was close to significance ($p \approx 0.084$), but those for differences between seasons within Thurston's data gave $p \approx 0.24$ and were not significant, and similarly comparing numbers by season between the two datasets ($p \approx 0.234$), did not give significance.

Variation in Cases by Lunar Phase

There is no data from Thurston the relationship between cases and the phase of the lunar cycle. However there is a tradition from antiquity which associates the full moon with affective disorders (Owens and McGowan, 2006) and the etymology of the terms lunacy and lunatic have the root *luna*- derived from the latin for moon. As discussed in Greatbatch et al (2019) there was no indication of any statistically significant increase in a variety of emergency incidents during full moon periods, however there is some divergence in the results of studies, for example Partonen et al. (2004) noted the marked increases around both Full Moon and New Moon phases, which could influence luminance levels although the impact of this in a relatively well-lit metropolitan area such as London is likely to be diminished compared to a study over a sparsely populated country like Finland.

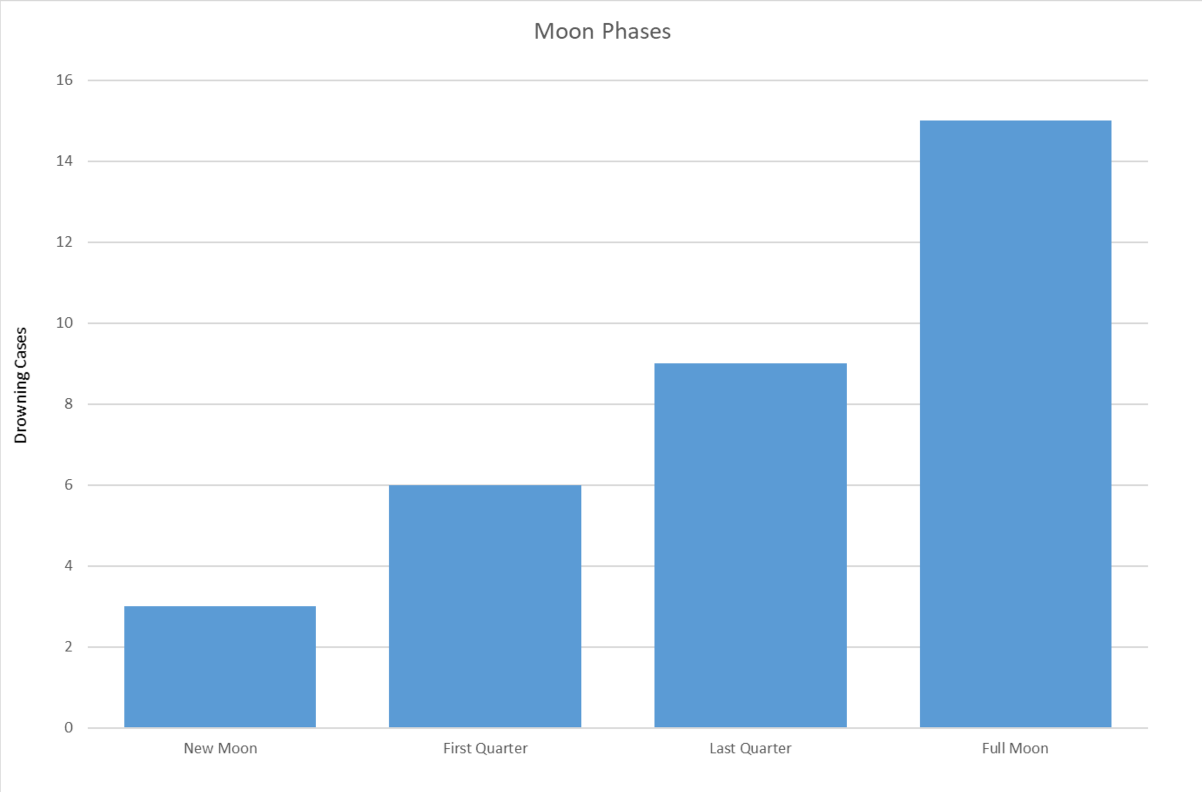

Figure 5: Lunar Phases for reported Drownings in the River Thames 2004-2015 (Metropolitan Police)

Statistical tests were carried out to investigate the significance of the variation of cases in the new (Met Police 2004-15) dataset by phase of the lunar cycle. Considering all four "quarter phases" of the lunar cycle, a Chi-Squared test gave a statistically significant result ($\chi^2 = 9.55$, DF = 3, $p \approx 0.023$), and comparing the "Full" quarter against the other three gave highly significant results both using a Chi-Squared ($\chi^2 = 7.36$, DF = 1, $p \approx 0.0067$) and a binomial "exact" test ($p \approx 0.0084$). This indicates that significantly more drowning cases occur (with the Met Police 2004-15 dataset) during the "full" quarter of the lunar cycle than at any other point of the lunar cycle.

There was a broad range of PMSIs with most being in the water under 5 days, but with 8 cases being submerged for between 10 and 20 days (Table 2, Figure 3). The range of distances travelled after entering the water was from 17m to 14.45km, with an average drift distance of 3.27km and 9 victims travelling more than 5km after entry. Thurston suggested an increase in 'early autumn' and August and October do represent the busiest months in this data, with no incidents in January (although this data only represents those victims with a known entry point, so there may well be data for those periods in the overall body recovery records). The distribution of cases by meteorological season can be seen in Table 8, and the spring and autumn rises in incidents observed. The average PMSI for winter is higher than any other season, which could suggest an impact of cold water on decomposition, but with only two cases in that season it is impossible to hypothesise with any confidence. Friday and Saturday were the most common days for the deaths, with Sunday the least common.

Clothing, Distance Travelled ("Downdrift") and Time in Water

There are 26 records in the present study that contain information on clothing, and these have been subdivided into groups by clothing weight. These weights were compared to distance travelled using Spearman's rank correlation coefficient since the clothing weights followed an ordinal rather than continuous scale. The results (Table 7) showed that there were weak (not statistically significant at 5% level) correlations between clothing weight time spent in the water, with heavier clothing tending to imply that the body spent less time in the water. Correlations between clothing weight and distance travelled (downdrift) and between time in the water and distance travelled were so weak as to be considered negligible ($p > 0.75$ in both cases).

The negligible correlation between time in water and net distance travelled between point of entry and point of removal from the river can be observed in the scatterplot (Figure 6). Negative distances (negative downdrifts) indicate that the particular body was displaced upstream, rather than the expected downstream. There is clearly no simple relationship between net distance travelled and time in the water. This is most probably again due to the oscillatory nature of the effect of tides, since all bodies had been in the river for seven days or more.

		days in water	Clothing score	downdrift
Days in Water	Correlation Coefficient	1.00	-0.18	0.06
	Sig. (2-tailed)		0.32	0.76
	N	33	33	33
Clothing Score	Correlation Coefficient	-0.18	1.00	0.00
	Sig. (2-tailed)	0.32		0.99
	N	33	33	33
Downdrift	Correlation Coefficient	0.06	0.00	1.00
	Sig. (2-tailed)	0.76	0.99	
	N	33	33	33

Table 6: Correlation results for clothing weight versus distance travelled (downdrift) and time in water. Spearman's Rank Correlation Coefficient was used with a two-tailed test of statistical significance. None of the correlations were statistically significant at the 5% level.

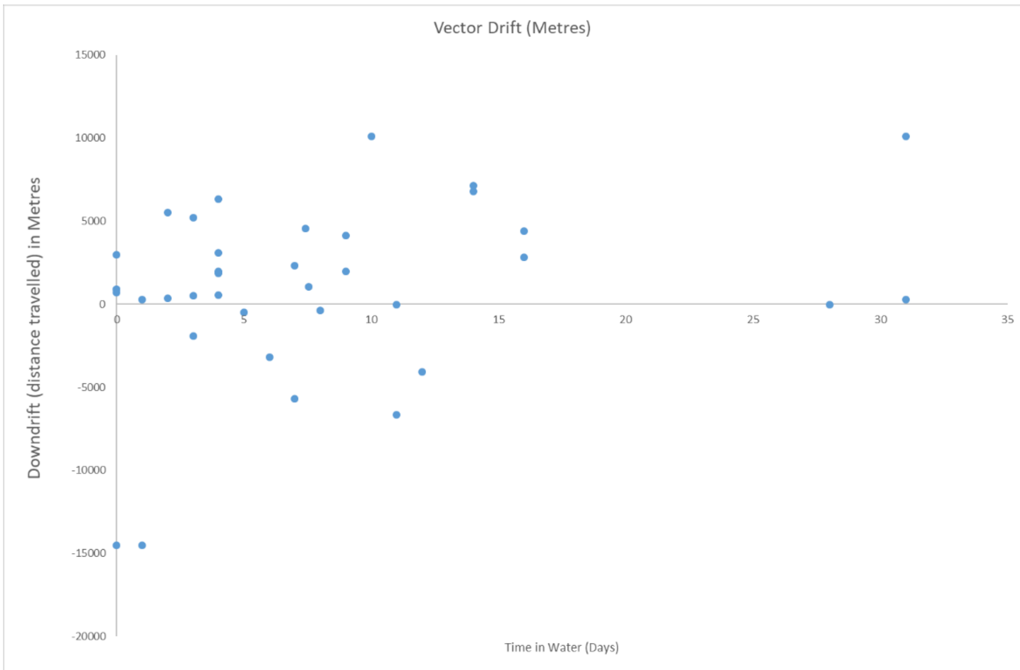

Figure 6: Downdrift of Recovered Bodies (metres) against Time in Water (days) 2004-2015 (Metropolitan Police)

Discussion & Conclusion

Clearly this an unusual dataset, and one that could only have been created or collected by an agency such as the River Police. It deals with a subset of recoveries from the river - those where a point of entry is known - and as such is prone to some of the well understood limitations of small datasets. Any pattern or inference made from the data must be considered in terms of the overall set size, yet in order to calculate the drift or submersion time of bodies, this is the only reliable data that could be used. Future technological advances, such as wearable technology, or an increase in the CCTV coverage on the River Thames may result in more complete datasets in the future.

The analysis has produced some notable results, which may have policy implications. Firstly, it can be seen that there are two seasonal spikes - around spring and autumn. For this we have two working hypotheses:-

1. It is related to a seasonal disorder: The daylight is either decreasing, summer holidays are finished, and the winter is coming. In late spring the later, lighter nights may reinforce feelings of isolation, if lonely people can observe activities occurring outside, yet they are not involved.
2. It is physically more dangerous: The two spikes coincide roughly with the equinoxes and as such the river is at its highest astronomical tidal heights. The driving factor behind an increase in deaths may be that the chances of survival are diminished at these times, rather than the input number of attempted suicides.

The negative correlation between clothing weight and time spent in water is perhaps counterintuitive. However, a possible explanation for this could be that the clothing level recorded is that observed when each body was recovered from the water, but not at the time of the body entering the river. The longer the body remained in the water, particularly bearing in mind the oscillatory influence of tides, the greater the opportunity for clothing to be removed from the body by natural processes such as abrasion against the riverbed, riverbanks or other objects in the water, as suggested by Armstrong & Erskine (13).

There is a dramatic imbalance of men to women, which appears to run counter to global, or regional statistics, and this may be something addressable through education, or social policy.

Many of the current campaigns such as the Royal Society for the Prevention of Accidents (ROSPA) "don't drink and drown" or the seasonal work concerning Men Missing on a Night Out (Newiss and Greatbatch, 2019) specifically address male accidental drowning and suicide around the Christmas holidays. This work potentially adds insight to male suicide figures in London, in terms of both seasonality and spatiality, which in turn may inform policy.

This work serves as a baseline study, in a field where little work has been completed (with the notable exception of Dennison-Wilkins 2021) and provides a set of analysed data and conclusions which would be hard to replicate without the input of the MPU. This work has the potential to form the basis of heuristics for body recovery search planning, and to inform search patterns for drowned victims in other bodies of water. The importance of this should not be underestimated, when considering the emotional impact on the families of drowned persons; in essence any tool that reduces the PMSI is likely to reduce traumatic impact on survivors.

As this work is essentially a baseline study with a specialist dataset, and limited to that, it provides much scope for further work. Increasing the size of the dataset would allow for a greater range of statistical tests to be performed, but would also give more confidence in some of the observed patterns. The size of the dataset could be improved by recording more cases of recorded entry into the water - by increasing the monitoring and recording on Thames - and matching them up with subsequent body recoveries. Other rivers could also be incorporated, and a comparative study of rivers performed. There is also potential for retrospective work on recovery-only cases, applying CCTV and other information from police or coroners reports to determine the point of entry.

Further experimental work could also be performed with clothing, using fixed dummies, or private rivers to investigate the rate of deterioration of clothing, and potentially even the impacts of different materials and garments on the movement and buoyancy of human bodies. Finally, there is some existing application to forensic science and policing in the analytical results concerning drift, but there is some potential in future work to use some of the results here to generate heuristics for predicting body location.

(no. of cases)	Gender		Age			Date of Entry (Most Frequent)			Drift Direction	
	Male	Female	Ave.	Max	Min	Season	Month	Moon Phase	Downstream	Upstream
All	32	1	36	79	20	{Spring, Autumn} n=11	{August, October} n=6	{Full Moon} n=15	23	10
Western Reach	12	0	39	62	21	{Summer} n=5	{August} n=3	{Quarter Moon} n=5	8	4
Central/Eastern	20	1	34	79	20	{Spring} n=9	{April, October} n=4	{Full Moon} n=11	15	6

	Drift Distance (m)			PMSI (Days)		
	Average	Max	Min	Average	Max	Min
All	3,273	14,517	16	8	31	0
Downstream	3,089	10,102	284	7	31	0
Upstream	3,696	14,517	16	9	28	1

Sex	Age	Drift Direction	Drift Distance (m)	PMSI (days)	Clothing weight	Month (Entry)	Moon Phase (Entry)	Season (Meteorological)
Male	35	UPSTREAM	4,089	12	3	MARCH	Last Quarter	SPRING
Male	20	DOWNSTREAM	4,408	16	1	MARCH	Full Moon	SPRING
Male	34	DOWNSTREAM	2,805	16	2	MARCH	New Moon	SPRING
Male	39	UPSTREAM	6,654	11	3	MARCH	First Quarter	SPRING
Male	23	UPSTREAM	377	8	2	APRIL	First Quarter	SPRING
Male	28	DOWNSTREAM	4,111	9	0	APRIL	Last Quarter	SPRING
Male	29	DOWNSTREAM	1,958	9	3	APRIL	Last Quarter	SPRING
Male	28	DOWNSTREAM	2,960	0	3	APRIL	Full Moon	SPRING
Male	59	DOWNSTREAM	2,336	7	0	MAY	Full Moon	SPRING
Male	45	UPSTREAM	3,192	6	0	MAY	Full Moon	SPRING
Male	30	UPSTREAM	475	5	2	MAY	Last Quarter	SPRING
Male	37	DOWNSTREAM	6,310	4	1	JUNE	New Moon	SUMMER
Male	35	DOWNSTREAM	291	31	4	JUNE	Full Moon	SUMMER
Male	54	DOWNSTREAM	897	0	3	JULY	Full Moon	SUMMER
Male	29	DOWNSTREAM	368	2	0	AUGUST	Full Moon	SUMMER
Male	40	UPSTREAM	1,931	3	4	AUGUST	Full Moon	SUMMER
Male	31	DOWNSTREAM	1,961	4	3	AUGUST	Full Moon	SUMMER
Male	45	DOWNSTREAM	284	1	4	AUGUST	Last Quarter	SUMMER
Male	21	DOWNSTREAM	3,084	4	0	AUGUST	Last Quarter	SUMMER
Male	27	DOWNSTREAM	1,869	4	2	AUGUST	Last Quarter	SUMMER
Male	24	DOWNSTREAM	5,212	3	2	SEPTEMBER	New Moon	AUTUMN
Male	23	DOWNSTREAM	554	4	2	SEPTEMBER	Last Quarter	AUTUMN
Male	32	DOWNSTREAM	5,501	2	3	SEPTEMBER	Full Moon	AUTUMN
Male	29	UPSTREAM	25	11	3	OCTOBER	Full Moon	AUTUMN
Male	62	UPSTREAM	5,687	7	1	OCTOBER	First Quarter	AUTUMN
Male	25	DOWNSTREAM	10,102	10	3	OCTOBER	First Quarter	AUTUMN
Male	50	DOWNSTREAM	525	3	3	OCTOBER	Full Moon	AUTUMN
Male	23	DOWNSTREAM	7,127	14	2	OCTOBER	Last Quarter	AUTUMN
Male	45	DOWNSTREAM	901	0	2	OCTOBER	Full Moon	AUTUMN
Female	79	UPSTREAM	14,517	1	3	NOVEMBER	Full Moon	AUTUMN
Male	25	DOWNSTREAM	6,768	14	0	NOVEMBER	First Quarter	AUTUMN
Male	48	DOWNSTREAM	709	0	0	FEBRUARY	Full Moon	WINTER
Male	23	UPSTREAM	16	28	4	DECEMBER	First Quarter	WINTER

Table 9. All data, anonymised.

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