International Journal of Aquatic Research and Education, 2013, 7, 116-135

Development and Trial of a Water Exposure Measure of Estimated Drowning Risk for Surf Bathers

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To better address drowning issues, risk assessment at the group and sample levels would be enhanced by precise measures of exposure to water. The aim of the study was to develop and pilot test a method of measuring exposure to water based on estimating immersions for surf bathers. Validated direct observation counts provided peak-bathing period point estimates and a daily bather immersion profile for an identified sampling frame comprising 20 beaches over 39 summer days. An estimated 10,089 water immersions occurred at the peak-bathing period in the sampling frame. Swimmers comprised 86.0% and surfers with equipment 14.0% of the observed bathing sample, respectively. For swimmers only on patrolled beaches, 77.1% bathed in the lifesaver supervised (flag) zones. The study has implications for the provision of organized bather supervision and provides a foundation for generation of hypotheses on the nature of drowning risk for selected surf bather groups.

Keywords: water exposure; drowning risk; surf beaches; methodology.

Drowning is a complex injury problem identified across numerous aquatic locations with an estimated 1.2 million drowning deaths occurring world-wide each year (International Life Saving Federation, 2012). Groups considered to be at relatively high risk of drowning include young children accessing backyard pools or other artificial water bodies, elderly persons in bathtubs, and adolescent or adult males swimming at beaches or other open water locations (Hayashi, Ago, Ago, & Ogata, 2010; Peden et al., 2008; Quan & Cummings, 2003). The International Life Saving Federation reports that for drowning deaths associated with recreational activities, 40% occur two meters or less from shore, and 25% occur in water depth below one meter.

Assessment of drowning risk for specified high risk groups or categories is often based only on a relatively higher fatal drowning frequency reported for locations and circumstances of interest or from resident population-based rates. Needless to say, drowning risk could be determined more accurately by applying more refined

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measures of exposure to water and other possible drowning risk factors (Robertson, 2007). Precise exposure measurement will determine, for example, whether drowning patterns simply reflect proportional levels of exposure to water. The alternate finding supports hypotheses associated with an identified group's exposures to drowning risk or protective factors.

Pless and Hagel (2005) acknowledge that exposure to risk is central to an epidemiological injury prevention approach but note that quantifying exposure can be "often bewilderingly complex" to the point where for drowning, "it is almost impossible to conceive of a denominator that truly reflects exposure to risk and that is feasible to measure" (pp. 184–5). Depending on the research question, potential measures and data for specifying drowning risk exposure over a given time-period include the number of water entries (immersions), duration time of water entries, location of water entries (e.g., backyard swimming pool or lifesaver supervised surf beach), sea and water conditions at the time of water entry, person or other situation factors, or some combination of these. This choice is important because the exposure measure in drowning risk used for analytical epidemiologic study (with adequate validity assumed) determines drowning rates, relative drowning risks, or drowning risk contributions from candidate factors. Any applied measure of water exposure will nevertheless still be an epidemiologically crude estimate of drowning risk in the sense that drowning risk contributions from all factors may not be accounted at the group or individual level. Morgan and Ozanne-Smith (2012, p. 338) provided an example of how a contradictory drowning risk assessment between age groups may result depending on the measure used to determine exposure to water. In this example, drowning risk for a defined group is shown to be relatively higher than a comparison group when based on immersion frequency and relatively lower when based on the duration of immersions.

Exposure to water or other drowning risk factors has been estimated by imprecise methods including self-report of past behavior or proxy measures such as pool ownership (Mitchell, Williamson, & Olivier, 2010; Morgan, Ozanne-Smith, & Triggs, 2009a; Pearn & Nixon, 1977). Certain drowning problems may lend themselves to more precise water exposure measurement.

Study Rationale

Surf beaches provide a potential location for developing and testing new methods to measure water exposure. Surf bather drowning is a recognized problem in many countries with the epidemiology described for some (Morgan, Ozanne-Smith, & Triggs, 2008). Sufficiently-sized surf bather samples may be obtained from beaches near population centers given the high visitation levels sustained during amenable weather conditions. Bathers are readily observable and the role of factors including environmental conditions and organized bather supervision may be recorded simultaneously. Such a measure of exposure to bather supervision may, for example, provide both an assessment of the safety service uptake and a comparison with self-reported survey data (Kellogg's & Newspoll, 2000).

As a supplemental benefit, better understanding of water exposure would enhance the value of currently available information associated with surf bather drownings. Relevant studies include descriptions of bathing duration, site preferences, beach use, risk perceptions, and dangers presented by environmental hazards

(Harada, Goto, & Nathanson, 2011; McCool, Moran, Ameratunga, & Robinson, 2008; Mercer, 1972; Morgan, Ozanne-Smith, & Triggs, 2009b; Sherker, Williamson, Hatfield, Brander, & Hayen, 2010; White & Hyde, 2010). Sourced mostly from self reports or observations from ecological studies, reported findings provide useful knowledge, particularly at the individual bather level. Reliable data shedding light on surf bathing patterns and estimated drowning risk over time at the large sample level would complement current knowledge.

Hence, the research reported here aimed to develop and pilot a suitable method for measuring water exposure by direct observation of a surf bathing sample based on water immersions. To support the methodological development, two objectives were assessed: (a) the accuracy of observed counts by comparison with independent counts and video recorded data, and (b) the accuracy of results based on comparison with a relatively less intensive sampling procedure.

Method

Surf bather water exposure data were measured by direct observation and recorded video for selected beaches situated in Victoria, Australia. Spatial and temporal sampling frames were determined in consideration of the research aim, data requirements, physical resources, location, access, and available research funding. Ethical approval for the study was granted by the Monash University Standing Committee on Ethics in Research Involving Humans, project no. 2001/431.

Spatial Sampling Frame

Short's (1996) system of Australian beach identification and description provided a basis for the study. The spatial sampling frame comprised 20 spatially consecutive wave-dominated beaches, spanning approximately 23 km of coastline following a southeast to northwest direction (see Figure 1; beach numbers 250–269 under Short's system). All beaches were located within the Mornington Peninsula National Park (on the Southeast Australian coastline), approximately 110 km by road from the Melbourne (2006 population = 3.7 million) central business district (Australian Bureau of Statistics, 2007). Access, size, environmental features, facilities, services, and amenities varied among the beaches. For example, three beaches had regular lifesaving patrols during the summer. Seventeen beaches were not patrolled by lifesavers during the study. On the three patrolled beaches, the lifesavers on duty closely supervised bathers within a narrowly defined zone. Bathers positioned outside this zone at these *patrolled* beaches may have been unsupervised. As explained below, bathing at patrolled beaches may occur distant from stationed patrols or outside patrol hours. In the study, data from the three patrolled beaches include both supervised and unsupervised bathing areas unless otherwise stated. The three patrolled beaches carried a National Park entrance charge, but also had toilets/ change rooms, dedicated car parks, and kiosk. Other beaches had no built facilities or services, with access for some limited to dirt walking tracks over 300 m. Beach lengths ranged from 50 m to 4000 m.

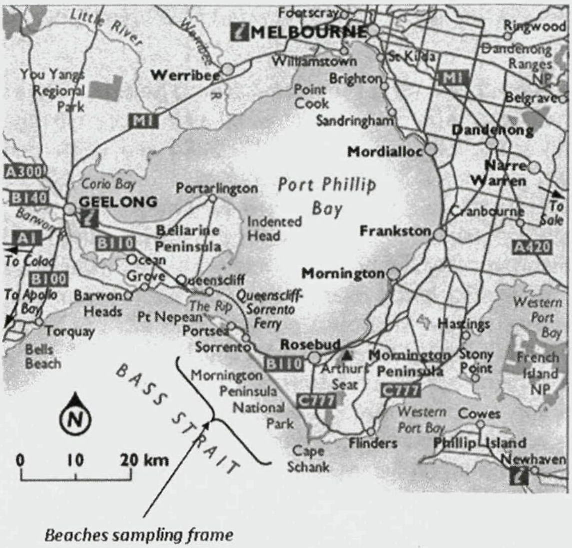

Figure 1 — Spatial sampling frame with respect to Melbourne city (map courtesy of Tourism Victoria, reproduced with permission).

Temporal Sampling Frame

The study was conducted during the midsummer school holidays in three time periods, from late December to late January (pilot, 2001–2002; time-period 1, 2003–2004; time-period 2, 2004–2005). These summer months were assumed the *busiest* for beach bathing due to the generally favorable weather conditions and the traditional holiday period.

Target Sample and Data Collections

The target sample was defined as beach bathers (i.e., waders, swimmers and surfers using equipment) meeting the sampling frame parameters. Mornington Peninsula National Park visitor records were extrapolated to provide proportions for sample stratification to increase the sampling precision for the study (Zanon, 2002). Based on these data, 47% of the research sample attended the three patrolled beaches and 53% the 17 unpatrolled beaches. With respect to day of the week, 42% visited on weekend days and 58% on week days.

For time periods 1 and 2, two sets of data were collected. Dataset 1 comprised counts of surf beach bathers in the water at a time-point within the 3-hour peak-bathing period (defined as 12:30 p.m.–3:30 p.m. established from pilot data). Dataset 2 comprised point counts of bathers in the water at half hour intervals for a single beach over a day (6:00 a.m.–8:00 p.m.) plus night spot checks, for time-period 1 only.

Dataset 1: Bather counts during the peak-bathing period. Data were collected by two trained research assistants for a planned 39 consecutive days (time-period 1) from December 20, 2003 to January 27, 2004 and (time-period 2) for 20 nonconsecutive days (over a 39 day period) from December 20, 2004 to January 27, 2005. Time-period 2 data were collected for comparison with time-period 1 data testing a more restricted and less resource intensive sampling procedure. To promote data heterogeneity for bather counts within the time-period 2 data, the sampling days were distributed over quartile air temperature ranges, based on average forecast maximums (degrees Celsius: below 22; 22–24; 25–28; over 28) and day type (13 week days, 6 weekend days and 1 public holiday) as these factor were presumed to be influential on beach visitation and ensuing bather levels.

Guidelines for sampling method and design were provided by vertebrate monitoring procedures (Thompson, White, & Gowan, 1998). For simple random surveys, sampling without replacement is the preferred option for providing unbiased estimates in smaller sample sizes. Because variables presumed to influence bather patterns varied across days (e.g., maximum temperature), each day was considered a discrete event. Therefore, beaches were randomly selected each day without replacement (no beach was observed twice or more in one day), but for each new sample day, all beaches selected the previous day were replaced for inclusion within the random selection.

The accuracy of large sample estimates of bather abundance (persons immersed in water) within the sampling frame at the peak-bathing period was contingent on the population size, sampling size, and sampling procedure. The size of the population to be sampled was from 780 beach-days (i.e., bather counts for 20 beaches over 39 days). The maximum feasible sample size of beaches was set at five randomly sampled from two strata for each survey day (comprising two from three patrolled and three from 17 unpatrolled beaches for time-periods 1 and 2). This number was based on available resources, the observation method (detailed below), and the required travel times between beach observations. An online calculator was used to determine random sampling order each survey day (Urbaniak & Plous, 2003).

The sampling plan for time-period 1 provided a sample size of 195 beach-days (five beaches over 39 days from a population of 780 beach-days) resulting in a 95% confidence level of the estimate being within ± 6.1% of the true population figure (Custominsight, 2007). Corresponding 95% confidence for the time-period 2 sampling plan estimate (100 beach-days—drawn from five beaches over 20 days—from a population of 780 beach-days) was ± 9.2%. These estimates assumed that no enumeration variance existed (i.e., all bathers in the water at each beach count can be observed and recorded accurately).

Dataset 2: Bather count profile over a daily period. To record the profile of variation in bather numbers over the daily period in the sampling frame, counts were recorded by the first author each half hour at 10 selected beaches from 6:00 a.m.–8:00 p.m. The method of observation and recording replicated that used for the peak-bathing period counts (see below). A purposive sample of high use beaches (from pilot) comprised five patrolled and five unpatrolled beaches. Five counts were taken on week days and five on weekend days. Four spot checks were taken between 9:00 p.m. and 11:00 p.m. on nights conducive to bathing. High-use beaches were counted so that individual bather group patterns would exert a relatively small effect on counts. Table 1 provides a summary of the sample counts and count populations.

Bather Count Procedure

The observation method for counting total numbers of in-water bathers (immersions) was developed and tested over 7 days during piloting. Bathers were readily identified. Distinguishing between swimmers and surfers using specialized wave-riding equipment (surfboards or body-boards) was straight forward. Bather sex and age were not readily identified so neither variable was recorded. Weather and water conditions were recorded onsite.

In Australia, direct and continuous bather supervision at patrolled beaches is restricted typically to a lifesaver-determined bathing zone identified by the aquatic space between two flags posted in the san[illegible] and adjacent to the wa[illegible]r (see Sherker et al., 2010) for a specified daily period (e.g., 10:00 a.m. to 6:00 p.m. in the summer season). Based on the first author's untested and limited observations, the distance between flags may be from 20 m up to around 70 m. Lifesavers, stationed at this zone, closely supervise bathers in the aquatic area identified between the flags and give less attention to bathers outside of this area (Surf Life Saving Australia, 2012). In fact, bathers outside lifesaver supervised zones on patrolled beaches may be over 1000 m distant from stationed patrols given the length of some of these beaches.

During the study observations, bathers were noted to congregate between the flags and were readily distinguished from those outside—the latter bather group was separated by enforced buffer zones. Bathers outside lifesaver supervised zones on patrolled beaches mostly comprised surfers using hard fiberglass boards not allowed in the flag zones for safety reasons. The use of soft body boards may be

Table 1 Date Collection Schedule for Bather Counts at Peak Bathing Period From a Sampling Frame of 20 Adjacent Beaches Over a 39-Day Period

	Patrolled Beaches		Unpatrolled Beaches		Total	
	Count	% of Count Population[a]	Count	% of Count Population[b]	Count	% of Count Population[c]
Time Period 1: 2003-2004—Over 39 Days						
Planned & Random	78	66.7	117	16.1	195	25.0
Daily Variation Count	5	0.4	5	0.1	10	0.1
Time Period 2: 2004-2005—over 20 days						
Planned & Random	40	34.2	60	9.0	100	12.8

Note. Patrolled beaches include both supervised and unsupervised bathing areas.

[a] Potential peak-bathing period point count was 117 patrolled beach-days.

[b] Potential peak-bathing period point count was 663 unpatrolled beach-days.

[c] Potential peak-bathing period point count was 780 patrolled and unpatrolled beach-days.

permitted in the closely supervised area at the discretion of the patrol captain (Surf Life Saving Australia, 2013). The location of bathers with respect to the lifesaver supervised zones (between the flags) was recorded during the counting procedure.

Obtaining accurate bather counts, particularly on high use days, proved difficult for several reasons: Some nonbathers (e.g., fully clothed persons standing at the shoreline) were immersed sporadically at the water's edge with the surge of passing waves; swimmers and surfers were hidden periodically behind or under swell and broken waves; the size of some beaches allowed bathing at far distances from the observer; one beach (Gunnamatta) was best observed from two discrete points as bathers close to the water's edge at point 2 may have been obscured at point 1 by a rocky outcrop. Fortunately, this reef formation observable at both points effectively split the beach and so facilitated discrete bather observations.

To obtain accurate bather immersion counts six procedures were undertaken:

1. The optimal observation point was identified at each beach based on elevation and shadow;
2. High powered wide angle binoculars were used for counting;
3. To provide identification of bathers (and exclusion of nonbathers), all persons observed in the water to a minimum of knee deep (approximately 50 cm for adults) during the count were included to designate constant and intentional exposure to water. Persons in shallow water below knees were theoretically at risk for drowning, of course, but were not considered in this study to be part of the bather sample;
4. Observation was conducted over an extended time-period to identify all bathers in wave zones (e.g., observing long enough for the passage of four to six waves);
5. A second count was conducted immediately (after a maximum two minute break if required) following the first count. The average of these two counts was then taken as the observed count, and;
6. For Gunnamatta Beach, this procedure was conducted at two observation points with results tallied.

Bather Count Reliability

The reliability of bather immersion counts observed and recorded at the peak-bathing period was assessed by interrater reliability (for time-period 1) and accuracy assessment based on a comparison of observed counts with counts from video recordings (for time-period 2). Interrater reliability was assessed by six comparison beach counts duplicating planned counts taken over four days. Duplicated counts did not coincide in time exactly with planned counts but remained within the specified peak-bathing period. Video footage was recorded directly following the observed count for each beach. The observer used a hand held digital video camera (8 mm) to pan bathers along the beach. Recordings were loaded as digital files to allow later counts directly from a computer screen; video data reduction was enhanced by screen freezing to count bathers from still images where required. The video counts were made independent of any reference to the observed counts.

Data Analysis

Collected data were entered on spreadsheets for statistical analyses. Bather count interrater reliability and video count comparisons (dataset 1) were estimated using Spearman rank order correlation coefficients (r_s), alpha $p < .05$, assuming a nonnormal distribution (Rosner, 2006). Bather counts taken for the peak-bathing period (dataset 1; 12:30 p.m.–3:30 p.m.) were used to estimate a total point count of immersions for the sampling frame (20 beaches over 39 consecutive days). This procedure estimated total daily sample-size within each stratum from the average of observed counts across surveyed beaches multiplied by the total number of beaches.

Summing the two strata (dataset 1; patrolled and unpatrolled beach counts) for the 39 survey days provided the sample-size point estimate at the peak-bathing period for the sampling frame in time-period 1 (Thompson et al., 1998, p. 52). In time-period 2, results summated for 20 survey days were extrapolated to the corresponding 39-day period. Sample-size estimates were used to calculate averages including bathers per day and per beach. Point estimates for the peak-bathing period immersions were calculated for surfers, swimmers, bathers between the flags (lifesaver supervised bathing zones), and beach type (patrolled or unpatrolled). Results for bathers within or outside the lifesaver supervised zones are reported for swimmers only (including waders but excluding surfers with soft body-boards or surfboards).

The resultant daily profile of water immersions (dataset 2; bather counts at 30 min intervals from 6:00 a.m. to 8:00 p.m. plus night spot checks) treated bather immersions as the unit of measurement. The total bathers reported for each half hour period (average) were calculated by summing bather counts (for each half hour) across the 10 data collection days.

Results

Bather Count Validation

Interrater reliability counts and corresponding planned counts for dataset 1 are reported in Table 2. The counts distributions recorded for time-period 1 were highly correlated ($r_s = 0.89$, $p = .019$), although the sample size of 12 observations in total was small. Aggregate results for the comparison between direct observation counts and subsequent video counts recorded for time-period 2 are presented in Table 3. Generally, comparison of counts with few bathers proved equivalent. At higher bather levels, the video counts were mostly lower than direct observation counts. Probable reasons include image clarity leading to difficulty in distinguishing exact numbers of people close by others in the water. A further reason for discrepancies may be the time difference between direct observation counts and video counts since people entered or left the water within a few minutes duration and wave swash quickly changed the water level and the subsequent number of bathers. Regardless of differences, statistical testing confirmed that direct observation counts and video counts were highly correlated ($r_s = 0.99$, $p < .001$).

Table 2 Interrater Reliability of Observed Immersion Counts at Peak Bathing Period for Selected Days and Beaches, Time-Period 1

		Planned Count		Interobserver Count	
Date	Beach	Time	Immersions	Time	Immersions
20 Dec.	20	12:30	26.5	12:45	22.5
20 Dec.	17	13:35	0.0	13:30	0.0
21 Dec.	4	14:12	134.5	13:00	192.5
21 Dec.	5	13:55	67.5	14:00	54.0
25 Jan.	20	14:05	66.0	12:15	66.0
26 Jan.	20	13:05	23.5	12:45	27.0

Table 3 Comparison of Observed Immersion Counts and Video Footage at Peak Bathing Period for Selected Days and Beaches, Time-Period 2

	Directly Observed Immersions	Video Recorded Immersions
Observations	100	100
Total bather count	3180.5	2947.0
Mean	31.8	29.5
SD	64.2	60.3
Median	2	2
Range	0-373	0-344

Dataset 1: Estimated Peak-Bathing-Period Immersions, Time-Period 1

Results from the bather counts for time-period 1 (2003–2004) are reported in Figure 2 and Table 4. Figure 2 shows the variability of bather immersion estimates across the 39 days for patrolled beaches, unpatrolled beaches and overall. Table 4 provides point estimates of the total bather immersions within the sampling frame and subcategory estimates at the peak-bathing period. Of the total estimated water immersions, 77.8% occurred at patrolled beaches and 22.2% at unpatrolled beaches.

Table 5 reports the proportion of swimmers (including waders) or surfers estimated within the sampling frame. Overall, surfers comprised 14.0% of the bather sample and swimmers 86.0%. The majority of both groups bathed at patrolled beaches. For swimmers on patrolled beaches, 77.1% were between the flags (lifesaver supervised zones) and across the entire sampling frame of patrolled and unpatrolled beaches, an estimated 3164 (37.6% from a sample of 8415 swimmers) did not bathe between the flags.

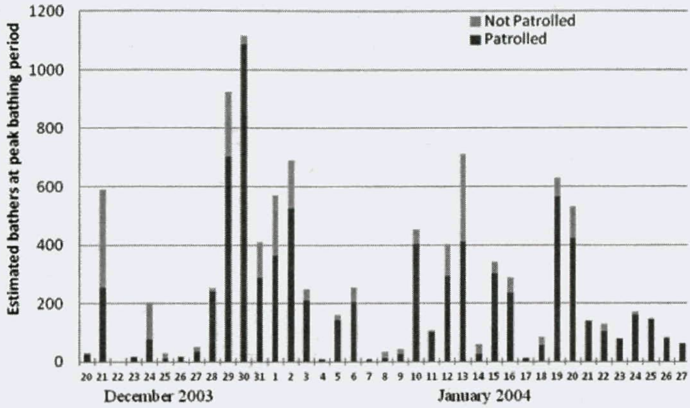

Figure 2 — Estimated bather immersions at peak bathing period for patrolled (n = 3), unpatrolled (n = 17), and overall (n = 20) surf beaches over 39 consecutive days, time-period 1.
Note. Patrolled beaches include both supervised and unsupervised bathing areas.

Table 4 Estimated Bather Immersions at Peak Bathing Period Over 39 Consecutive Days, Time-Period 1

	Research Frame of 20 Consecutive Beaches		
	Patrolled (n = 3)	**Unpatrolled (n = 17)**	**All Beaches (n = 20)**
Total	7851	2238	10,089
Total per day			
Mean	201.3	57.4	258.7
SD	229.1	84.4	278.8
SE	36.7	13.5	44.6
Median	140.3	22.7	145.5
Range	0-1087.5	0-337.1	0-1115.8
Per beach for 39 days			
Mean	2617.0	131.7	504.5
Per beach per day			
Mean	67.1	3.4	12.9

Note. Patrolled beaches include both supervised and unsupervised bathing areas.

Table 5 Estimated Mean Bather Immersions at Peak Bathing Period by In-Water Activity and Beach Type Over 39 Consecutive Days, Time-Period 1

	In-Water Activity			
Bather Immersions Per Beach	**Surfers**	**%**	**Swimmers**	**%**
Patrolled	349	90.4	2 268	96.0
Unpatrolled	37	9.6	95	4.0
Total	*386*	*100*	*2 363*	*100*
	In Flags	%	Outside Flags	%
Average Swimmer Immersions: Patrolled Beaches Only	1750	77.1	518	22.9

Note. Patrolled beaches include both supervised and unsupervised bathing areas—in flags refers to the closely supervised bathing area.

Dataset 1: Estimated Peak-Bathing Period Immersions, Time-Period 2

Results from data collected in time-period 2 (2004–2005; 20 sampled days selected over the 39 day sampling period) are presented in Figure 3 and Tables 6 and 7. Although based on relatively limited and purposefully-selected sampling days, the time-period 2 estimates for peak-period water immersions were similar in pattern and proportion to time-period 1 estimates. Total persons estimated for the 39-day period were higher for time-period 2 (overall 11,429 vs. 10,089 bather immersions in time-period 1 at the peak-bathing period). It is not clear how much of the observed differences resulted from sampling error or true differences in bather numbers. Across the entire sampling frame, 57.4% of swimmers (i.e., excluding surfers) bathed within the flags based on an estimated sample of 8383 (in time-period 1 this figure was estimated at 62.4%).

Dataset 2: Observed Water Exposure Profile Over a Daily Period, Time-Period 1

No bathers were observed at the four night spot counts. Total bather numbers are depicted in Figure 4. The distribution peaked at 1:00 p.m. with 771.0 bathers recorded. Bather counts followed a steep rise leading to this peak time. Following the peak, the fall in bather counts was relatively gradual. The generally concave curve pattern was marked by three minor peaks: at 8:30 a.m. (63.3), 3:00 p.m. (500.0), and 4:30 p.m. (365.5).

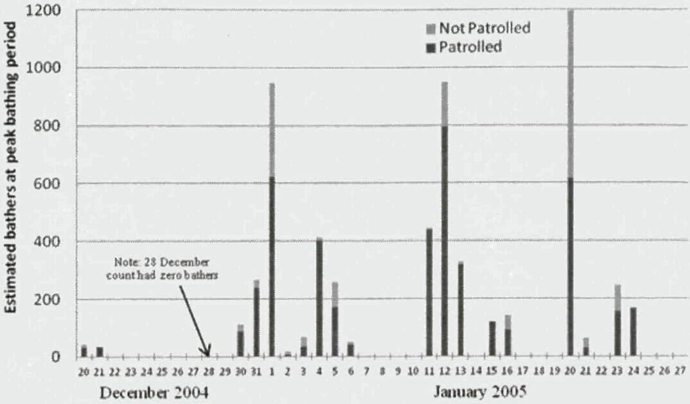

Figure 3 — Estimated bather immersions at peak bathing period for patrolled (n = 3), unpatrolled (n = 17), and overall (n = 20) surf beaches for 20 selected days, time-period 2.
Note. Patrolled beaches include both supervised and unsupervised bathing areas.

Table 6 Estimated Bather Immersions at Peak-Bathing Period Over 39 Days, Time-Period 2

	Research Frame of 20 Consecutive Beaches		
	Patrolled (n = 3)	**Unpatrolled (n = 17)**	**All Beaches (n = 20)**
Bather immersions for 39 days (based on sample size of 20 days)			
Total	8562	2868	11,429
Total per day			
Mean	219.5	73.5	293.1
SD	236.2	141.3	345.8
SE	52.8	31.6	77.3
Median	137.6	17.0	154.5
Range	0–795	0-578	0–1195.3
Per beach for 39 days			
Mean	2853.8	168.7	571.4
Per beach per day			
Mean	73.2	4.3	14.7

Note. Patrolled beaches include both supervised and unsupervised bathing areas.

Table 7 Estimated Mean Bather Immersions at Peak Bathing Period by In-Water Activity and Beach Type Over 39 Days (From a Sample of 20 days), Time-Period 2

	In-Water Activity			
	Surfers	**%**	**Swimmers**	**%**
Bather immersions per beach				
Patrolled	588	88.6	2266	96.0
Unpatrolled	75	11.4	93	4.0
Total	663	100	2359	100
	In Flags	%	Outside Flags	%
Average swimmer immersions: Patrolled beaches only	1604	70.8	662	29.2

Note. Patrolled beaches include both supervised and unsupervised bathing areas—in flags refers to the closely supervised bathing area.

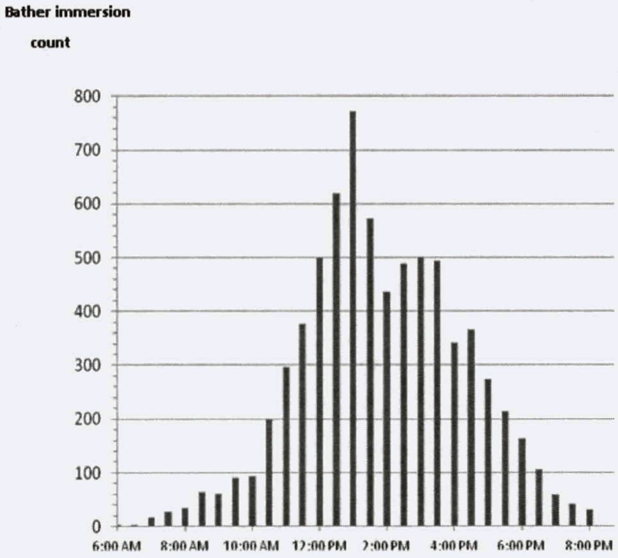

Figure 4 — Observed water exposure profile over a daily period for 10 beach days, time-period 1.

Discussion

This study developed and pilot tested a data collection method for obtaining valid and generalizable measures of water exposure for a sample of surf bathers. Three key outcomes support the cogency of the methodological development. Firstly, the reliability and accuracy of observed bather immersions counts were established by high and statistically significant correlations between these counts and corresponding interrater observation counts and video data counts. Secondly, similarity between bather immersion estimates from two discrete summer periods using different sampling procedures, to a degree, validated the results. Thirdly, the method of direct observation provided data from which bather water exposure over daily periods and across days could be estimated.

Systematic Bias in Observations

Although high count reliability was supported by the correlations, differences between direct observation and hand-held video recording in high-use bather periods indicate that exact agreement of the results between the two methods was not always obtained. This is not surprising. Thompson et al. (1998) used the term "detectability" for the probability of systematic bias introduced by this form of count error. In the absence of exact agreement between measures, the extent of bias is uncertain. For such cases, Cochran (1977, p. 14) proposed that bias in the accuracy of the sampling estimate may be considered negligible where average error is less than 10% of the sample standard deviation (based on a normal distribution). As the mean score difference between direct observation and video recording (Table 3) fell within this range, systematic bias from detectability was presumed to have no significant effect on bather-immersion estimates.

Dataset 1: Characteristics of Peak-Bathing Period Water Exposure

The distribution of bathers at the peak-bathing period (12:30 p.m.–3:30 p.m.) was characterized by a positively-skewed distribution (i.e., majority of counts clustered around low values and a long right hand tail (i.e., a few very high bather counts). This pattern is commonly found in count data of events. Such nonnormal (i.e., skewed) distributions for bather immersions in both survey time-periods suggest that mean estimates per beach, per day and per beach-day should be interpreted with caution because the variability in bather immersions was affected by a variety of variables such as weather, temperature, and day of week.

At the peak-bathing period, over 10,000 bathing episodes were estimated to have occurred in the sampling frame (20 beaches over 39 days). Across all 20 beaches each day, approximately 146 bathers were in the water at the peak-bathing time, based on the median score for time-period 1 data (Table 4). Comparable results were found for time-period 2. No drowning deaths were reported within the sampling frame (from data reported by Morgan et al., 2008). It is therefore not possible to estimate the sample's crude drowning risk from the study results, but by implication this rate would fall somewhere below 1 per 10,000 immersions measured at the peak-bathing period.

Dataset 2: Characteristics of Water Exposure Profile Over a Daily Period

Over the daily period, the profile of bather numbers at half-hour intervals followed a predictable path. Bather numbers rose sharply after 10:00 a.m. until the 1:00 p.m. apex. The relatively smooth decline in bather numbers after 1:00 p.m. is assumed due partially to beach visitors normally bathing more than once during their visit before afternoon departure (Morgan et al., 2009a). In addition, each count was influenced by the relative number of beach arrivals and departures in the half hour period leading to it. Subsequent minor peaks (illustrated in Figure 4) at 8:30 a.m., 3:00 p.m. and 4:30 p.m. are likely to be explained respectively by visitor departures following a morning bathe and visitor arrivals after lunchtime and later after the workday, when ultraviolet light is reduced, outweighing beach arrivals and departures for that period immediately preceding the count.

Relationship Between Water Exposure Based on Immersions and Drowning Risk

As stated earlier, the selection of immersion data to measure water exposure, and hence an estimation of drowning risk, necessarily excludes potential influences on drowning risk captured by other measures such as bathing duration or distance from shore. Although they have definite limits to their precision, peak-bathing period immersions data do provide a foundation for developing even more precise drowning risk estimates compared with those based on resident populations or self-reported data. For example, combining these data (dataset 1) with the recorded daily bather immersion profile (dataset 2) specifies total bather exposure over a day as a function of peak-bathing period exposure, following the method developed by Deacon and Kolstad (2000). This computation may then be combined with corresponding bathing duration estimates to determine total drowning risk exposure for a specified sample. Even so, the findings of this study based on immersions only have implications for drowning risk analysis and safety service resourcing.

Implications

For the 20 beaches over 39 days, three patrolled beaches together accounted for over two-thirds of bathers during the peak-bathing period. The findings indicate the bathing frequency ratio of a patrolled beach to an unpatrolled beach was 17:1 in time-period 1 (2003–2004) and 20:1 in time-period 2 (2004–2005). If estimated visitation from national park data cited in the method section (Zanon, 2002) is accurate, then it appears that visitors to patrolled beaches are more likely to bathe compared with those visiting unpatrolled beaches. As noted earlier, patrolled beach bathers may bathe within or outside the lifesaver supervised zones (i.e., between the flags).

Across Australia, unpatrolled beaches comprise 93% of accessible beaches (Morgan, 2003). In the current study, unpatrolled beaches made up 85% of the sample. Assuming this study's results generalize to national differences in bathing patterns between patrolled and unpatrolled beaches, then approximately 75% of Australian surf bathers use a patrolled beach, though not necessarily in a closely supervised area. It has been reported that 69% of surf bather drownings occur at a patrolled beach (Morgan, 2011). This comparison indicates that the crude drowning rate between patrolled and unpatrolled surf beaches is approximately proportional to crude water exposure patterns (based on bather immersions), suggesting that similar drowning risk operates at both beach types.

Results from this study demonstrate a significant proportion of patrolled beach bathers presumably are protected from drowning by bathing in the lifesaver supervised zones. For swimmers only including waders in time-period 1 on all beaches, the majority (77%) were observed within the lifesaver supervised zones (between the flags) at the peak-bathing period. Comparable results were found for the time-period 2 data collection. Morgan et al. (2008) reported just one out of 129 surf bather drowning deaths over a four-year period in Australia was recorded to have occurred between the flags. Fenner, Harrison, Williamson, and Williamson's (1995) statistical study of surf lifesaver resuscitations—for the Australian state of Queensland from 1972 to 1993—demonstrated that the likelihood of successful resuscitation increased closer to the lifesaver supervised zone. Both studies support the effectiveness of organized supervision as a protective factor to prevent surf drowning

From the study results, it is hypothesized that bathers outside the lifesaver supervised zones at patrolled beaches have a higher crude risk of drowning relative to both bathers between the flags on patrolled beaches and bathers at unpatrolled beaches. This hypothesis requires further assessment but if supported then a possible explanation may involve differences in perceptual or psychological determinants of bathing intention and behaviors for bathers in lifesaver supervised zones when compared with other bather groups at patrolled beaches (Sherker et al., 2010; White & Hyde, 2010). For example, bathers outside lifesaver supervised zones mindful that a beach is periodically patrolled may believe it to be safer even though a patrol is not proximate to the bathing location.

A minority of the bathers (e.g., 14% in period 1 based on totals reported in Table 5) used surf equipment including surfboards or body-boards. This estimation of proportional crude water exposure corresponds approximately with drowning death data, where 16% of recreational surf bather fatalities were associated with surf craft, suggesting that floatation devices (e.g., surfboards) do not offer drowning protection (Morgan et al., 2008). Further investigation is required because surfers on average may be exposed to higher drowning risk conditions (e.g., larger waves, greater distance from shore) and over longer durations compared with swimmers or waders though this may be compensated by greater aquatic skills and experience in surf.

Safety Service Resourcing at Surf Beaches

The documented substantial spatial and temporal variation in bather numbers makes obvious the difficulties faced by authorities when planning resource requirements for organized bather supervision. It follows that identification of observable factors that predict bather exposure from data comparable to that collected in this study would assist management of supervision resources. For example, surf lifesaver *outposts* in radio contact with patrolled zones may be positioned at unpatrolled beaches for days of predicted high bathing. Nevertheless, the spread of patrons across beaches suggests that it is neither practical nor conceivably possible to supervise all bathers using coastal surf beaches. This finding amplifies the importance of educational awareness and skill training to make surf bathing safer for unsupervised bathers or to discourage bathers from entering the water outside lifesaver supervised zones.

This study found that approximately two out of every five swimmers did not bathe within a lifesaver supervised zones at the peak-bathing period (time-period 1–42.6% and time-period 2–37.6% of the samples). This finding corroborates a random survey (via telephone) of 1,200 adults by Kellogg's and Newspoll (2000), which found that 61% of Australian beachgoers report always swimming between the flags (lifesaver supervised zones). Lifesaver supervised zones may play an important role where novice bathers learn necessary surf-related skills in a supervised environment. This drowning prevention strategy should be promoted as a suitable location for surf skill training and enhancement.

Limitations

The method used to collect dataset 1 was based on random sampling with stratification to increase precision. It is not possible to determine the accuracy of estimates without comparison with census counts (Thompson et al., 1998). Nevertheless, differences in daily point count sampling procedures between strata (three samples of 17 unpatrolled beaches and two samples of three patrolled beaches per sampling day) lend relatively greater confidence to the accuracy of the patrolled beach bather estimates. The method used to derive a daily profile was based on a limited (dataset 2; $N = 10$) and purposefully-selected sample with associated unknown bias including the potential for *double counting* immersions lasting over 30 min. Moreover, the method of estimation used here (bathers as the unit of analysis rather than using a ratio of bathers per beach-day) gave weight to the bathing profile on high use days. It may not accurately represent a profile of *average* variation.

A key limitation, associated with generalizability, is the study's narrowly-defined sample. A case may be made for the target sample being representative of Victorian surf bathers over summer but it is unknown whether this would be comparable to surf bathing samples located elsewhere or for other seasons. It is clear from the study that point exposure to water may be estimated to determine a sample's crude drowning risk (e.g., drowning rate per 100,000 bather immersions at the peak-bathing period) but measuring this behavior at the population level to *match* national drowning incidents (i.e., the population of Australian surf bathers for a specified time-period) would require significant research effort and resources.

The study assumed estimated drowning risk based on exposure to immersions for reasons of practicality and simplicity. That is, all bathers immersed were presumed to carry equal risk regardless of factors such as weather and water conditions, equipment, distance from shore, bathing duration, and surf experience. At the individual level immersions may not be a true reflection of drowning risk but at the group and sample level this provides a component in the search for a more precise measure compared with that currently available. Future studies may account for known influences to specify a more precise level of drowning risk faced by surf bathers (Morgan & Ozanne-Smith, 2012).

Conclusion

This study provides a method to observe and estimate point exposure to water by recreational bathers. Employing this method across larger research sampling frames will supply more specific information on bathing exposure and estimates of drowning risk (by application of comparative or contemporaneous fatal and nonfatal drowning data) and also allow evaluation of supervision resourcing. For high use recreation settings, technologically-sophisticated methods may be required (e.g., use of high image quality cameras). For example, high resolution surf cameras now located at beaches may provide a tool for measurement of water exposure (sample surf cam footage can be found at: http://www.coastalwatch.com) with technical advances underway (Green et al., 2006).

Acknowledgments

Required national park access was provided by the Department of Sustainability and Environment Research Permit 10002639. The study was completed as part of the first author's PhD candidature and data collection was funded by the Monash University Accident Research Centre (located within the Monash Injury Research Institute). The authors wish to acknowledge the contribution made by the late Professor Tom Triggs in developing and refining this study.

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