Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-143
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 25 June 2018

Natural Hazards and Earth System Sciences
Discussions

Title: Rip current rescues and drowning in the United States

Authors: B. Chris Brewster,[1] Richard E. Gould,[1] Robert W. Brander[2]

[1]United States Lifesaving Association, P.O. Box 366, Huntington Beach, California 92648

[2]School of Biological, Earth and Environmental Sciences, UNSW Sydney, Sydney, NSW Australia 2052

Abstract:

Rip currents are the greatest hazard to swimmers on surf beaches, but due to a lack of consistent incident reporting in many countries, it is often difficult to quantify the number of rip current related rescues and drowning deaths occurring along surf beaches. This study uses rescue data reported to the United States Lifesaving Association (USLA) by surf beach lifeguards from 1997 through 2016 to provide an estimate of rip current related rescues in the United States. Results show that rip currents are the primary cause of 81.9% of rescues on surf beaches, with regional variation from 75.3% (East Coast) to 84.7% (West Coast). These values are significantly higher than those previously reported in the scientific literature. Using this value as a proxy when examining overall surf beach related drowning fatalities, it is suggested that an annual figure of 100 fatal drownings per year due to rip currents in the United States is possibly an under-estimate. However, it is clear that the United States data would benefit by an increase in the number of lifeguard agencies which report surf related rescues by primary cause.

Keywords: beach safety, beach hazard, coastal hazard, lifeguards

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-143
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 25 June 2018

Natural Hazards and Earth System Sciences
Discussions

1. Introduction

On beaches around the world characterized by wave breaking activity across surf zones (herein referred to as 'surf beaches'), it is well established that the primary cause of rescues conducted by lifeguards, as well as fatal drownings, are rip currents (e.g. Klein et al., 2003; Gensini and Ashley, 2010a; Brighton et al., 2013; Brander and Scott, 2016). Rip currents are strong and concentrated flows of water moving away from the shoreline that are driven by alongshore variability in wave breaking and energy dissipation (Castelle et al., 2016). They are complex and variable features that are manifest as diverse types, which can be both persistent and transient in occurrence and location, may occupy deeper channels between shallower sand banks or lack any morphologic expression at all, and can occur along open stretches of beaches, both oceanic and lacustrine, or against hard structures such as headlands or piers (Castelle et al., 2016).

Typical rip currents are on the order of 5-50 m wide and extend to the seaward limit of the surf zone, where they may re-circulate, or extend past the surf zone variable distances offshore (Castelle et al., 2016). Mean rip current flow speeds over sustained periods (hours) are on the order of 0.3-0.5 ms^{-1}, but rips can experience short-lived pulsations of 2 ms^{-1} or more (MacMahan et al., 2006) making them a significant hazard to swimmers or waders of all swimming abilities who may find themselves caught in one. Inexperienced surfers and bodyboarders can also be imperiled by rip currents (Attard et al., 2015).

There has been a significant and recent increase in research relating to both physical and social aspects associated with the rip current hazard (e.g. Hatfield et al., 2012; Brannstrom et al., 2014; McCarroll et al., 2014; Scott et al., 2014; Castelle et al., 2016b; Houser et al., 2017). However, an ongoing challenge in addressing the actual societal and economic impact of the rip current hazard for beach safety practitioners, governments, and scientist alike is obtaining accurate values of the number of rip current related lifeguard rescues and fatal rip current drownings. In terms of the latter, two key factors make it impossible to determine the number of deaths caused by rip currents with complete accuracy.

First, it is well established that the majority of fatal rip current drownings occur on beaches unpatrolled by lifeguards, or outside of seasonal or daily beach patrol times (Branche and Stewart, 2001; Brander and Scott, 2016; SLSA, 2017). In some of these incidents, there are simply no eyewitness accounts available to help determine the cause of drowning. In others, drowning deaths are observed, but by people lacking necessary awareness and understanding to correctly attribute the role (if any) of a rip current in a drowning.

Second, in many countries there are no national requirements for reporting the causal factors (such as rip currents) in coastal drowning deaths. Even in countries that do, such as Australia (Brighton et al., 2013) and Costa Rica (Arozarena et al., 2015), the documented number of rip current fatalities is likely underestimated for the reasons previously noted. For example, while Brighton et al. (2013) determined an average of 21 rip current related fatalities on Australian beaches per year, they emphasized that this value was an underestimate as it was based only on confirmed rip current related drowning deaths.

The United States, with thousands of kilometers of coastline affected by rip currents and hundreds of millions of beachgoers each year, presents a challenge in accurately determining the number of rip current related drownings that occur. There are five distinct coastal regions characterized by different wave climates and physical characteristics, such as geologic setting and beach type: i) the continental Pacific west coast; ii) the Atlantic east coast; iii) the Gulf Coast; iv) the coastlines of the Great Lakes; and v) the Hawaiian Islands. Air and water temperature differences, as well as beach user demographics and beach usage, can also vary greatly between these regions, creating variable ‘swimming seasons’ throughout the country

The complex forcing mechanisms associated with rip current formation, type and location both within and between these regions not only leads to exposure to the rip current hazard being extremely variable spatially and temporally, but also makes it impossible to provide even a gross estimate of the occurrence and location of rip currents on United States beaches at any given time. Similarly, although some coastal U.S. National Weather Service (NWS) offices receive daily reports on rip current activity from lifeguards to assist in evaluating and disseminating their

public rip current hazard advisory (Houser et al., 2017; Moulton et al., 2017), these reports do not typically include the specific type, location or number of rip currents.

Perhaps most importantly, as in other countries, the presence of lifeguards on U.S. beaches is temporally and spatially variable. While some beaches have lifeguard beach patrols year-round, and two (Los Angeles County and San Diego) staff lifeguards 24-hours a day, others are staffed seasonally or are completely unstaffed (not patrolled). As such, there are many periods of time and beaches where lifeguards are absent. The breadth of services provided by U.S. lifeguard agencies also varies tremendously. Some are staffed and funded as primary providers of public safety, with a variety of advanced training and equipment, such as oceangoing rescue vessels, 9-1-1 answering points, and advanced medical training. Others provide more basic services with limited technology (USLA, 2017).

Despite these challenges, several attempts have been made to quantify the number of rip current related fatalities on U.S. beaches. Lushine (1991) combined documented rip current drowning fatalities in Florida, North Carolina and Alabama with various nationwide drowning statistic databases to estimate that 150 rip current related fatalities occur each year nationally. Gensini and Ashley (2010a) used Lexis Nexis, an online archive of newspaper articles sourced from local and national newspapers, combined with the National Climatic Data Center's (NCDC) *Storm Data* database (which uses a wide variety of sources from emergency management officials to newspaper clipping services), to conclude that on average 35 people die from rip currents in the U.S. each year. In contrast the United States Lifesaving Association (USLA) have estimated that rip current fatalities in the US can exceed 100 per year. This USLA estimate was arrived at internally in 2004 through a two-step process outlined in documentation submitted to the National Weather Service (USLA, 2004) that is provided here as supplementary material . First, the number of deaths each year at surf beaches was estimated based on several published studies. Second, the USLA theorized that the percentage of rescues from drowning due to rip currents, based on reports by lifeguards at surf beaches (then found to be over 80%), is a proxy for the relative proportion of surf drowning fatalities due to rip currents in the absence of rescue, and applied that percentage to the total number of estimated surf beach deaths (USLA, 2004). The discrepancies among these three estimates bear further evaluation.

Since 1966, the USLA has been soliciting annual data from beach lifeguard agencies around the country including the number of rescues from drowning, the cause of those rescues, the number of medical aids provided, drowning fatalities, estimated attendance, and many other data points. Lifeguard agencies are managed independently of the USLA, which sets recommended operational guidelines. These agencies are only obligated to report annual statistics to the USLA if they are "certified" (accredited) by the USLA, although they are welcome to report regardless of certification status. The USLA is the only national group collecting this data. Most, though not all, lifeguard agencies reporting data to the USLA serve surf beaches where rip currents are present. In 2016, the final year of data included in this study, there were 150 USLA certified agencies nationwide, varying in size from Los Angeles County and California State Parks on the large side (over 700 lifeguards each), to very small agencies with as few as 10 lifeguards.

As noted, one of the data points collected by the USLA is rescues from drowning, including those from rip currents. Those reporting are surf lifeguards trained to identify and rescue people from distress in rip currents. As noted earlier, the USLA, based on an evaluation of the data it collects, has consistently reported over many years that the primary cause of over 80% of rescues from drowning by lifeguards at surf beaches is rip currents and that in some areas this proportion is higher. However, two independent published studies have reviewed USLA data and come to different conclusions from the USLA regarding the percent of rip current caused rescues. Gensini and Ashley (2010b) reviewed the USLA data from 2000 to 2009 and concluded that roughly 36.5% of rescues reported to the USLA in those years were due to rip currents. Brighton et al. (2013) reviewed the USLA data from 2005 to 2011 and concluded that 53.7% of the rescues reported to the USLA were due to rip currents. Thus, three sources, reviewing similar data, although during different time periods, have come to widely varying conclusions about what the data collected and reported by the USLA shows (Brewster, 2010; Brewster and Gould, 2014).

Rescues from rip currents at beaches where lifeguards are present and report their data can provide insight into the magnitude of the hazard and may be useful as a proxy for the percent of drowning deaths at surf beaches. The primary aim of this study is therefore to accurately evaluate and report the percentage of rescues from rip currents by lifeguards reporting to the

USLA. We also aim to determine why researchers have come to vastly different conclusions as to what the USLA data shows and comment on the USLA estimate that rip current related drowning fatalities in the U.S exceed 100 per year.

2. The United States Lifesaving Association (USLA) Dataset

The USLA refers to itself as "Americas nonprofit professional association of beach lifeguards and open water rescuers" (USLA, 2018a). The USLA does not directly train or certify beach lifeguards, but rather promulgates training standards and certifies (accredits) lifeguard providers (agencies) that choose to apply and that are found to meet USLA requirements. These lifeguard agencies are typically funded by federal, state, and local governments, as well as a few private entities, some working as contractors to governments.

Many public and private beach lifeguard agencies in the United States record work output and beach observations in a manner similar to that of police and fire agencies. The resulting data offer measures of the services provided and help guide staffing and budgeting decisions. Each year many lifeguard agencies report this data to the USLA. In the most recent full year of reporting (2016), 150 lifeguard agencies reported. These rescue reports vary in magnitude from Los Angeles County, which reported 12,956 rescues from drowning that year, to much smaller agencies that reported as few as one rescue (USLA, 2018b).

The USLA has suggested a variety of metrics that should be used by beach lifeguard agencies to encourage overall consistency of reporting. These metrics include actual work output, such as rescues from drowning and medical aids performed, drowning deaths, and many other data points. They also include estimates of beach attendance. Annual summaries and the underlying data provided to the USLA are published and made freely available at: www.usla.org/statistics.

One of the key data points reported to the USLA is the number of rescues from drowning. For purposes of reporting, the USLA defines rescues as "*Total persons who are judged to be in imminent peril and brought to safety by a lifeguard. Usually involves physical contact. Does not include people who are given oral instructions to move to a safer location*." (USLA, 2018b).

183
184 The USLA also encourages agencies to document and report the primary cause of distress that
185 led to the rescue. The primary cause reporting options for rescues include: '*surf*', '*rip current*',
186 '*scuba*', and '*swiftwater*'. Agencies may choose none of these if they do not categorize the
187 primary cause of rescue or if none of these categories apply to a given rescue. '*Surf*' refers to
188 rescues in response to people who find themselves in distress due to the action of breaking waves
189 or being out of depth. '*Rip current*' refers to rescues in response to people caught in rip currents.
190 '*Scuba*' refers to rescues involving scuba divers. '*Swiftwater*' refers to people in distress in
191 inland areas due, for example, to river flooding, and are therefore not rip current related.
192
193 Data on rescues is typically tabulated in rescue reports by the lifeguards who effect the rescues.
194 USLA training materials include extensive information on identifying rip currents and rescuing
195 people in peril from rip currents (USLA, 2017). The rescue reports are compiled by the agencies
196 and subsequently reported annually, via an online reporting system, to the USLA. Prior to the
197 initiation of an online reporting system, reports were submitted manually via mail or email. The
198 transition to electronic reporting occurred gradually, beginning in the late 1990s.
199
200 One of the challenges for reviewers of data reported to the USLA is that reporting lifeguard
201 agencies are under no obligation to tabulate or report the primary cause of distress that led to the
202 rescue. For example, in a given year one agency might report 50 rescues broken down by
203 primary cause, but another agency may simply only report 50 rescues (no primary cause). If the
204 total number of reported rescues for the year is compared to the total number in which rip
205 currents were identified as the primary cause, without factoring out those agencies that failed to
206 report a primary cause, then the actual proportion of rescues related to rip currents (or other
207 primary causes) is diluted.
208
209 A second challenge for reviewers of USLA data is that some reporting agencies are solely
210 responsible for inland areas, such as reservoirs and rivers, where surf and rip currents are not
211 present (the Great Lakes, where rip currents are present, are an exception.) Nevertheless, these
212 agencies' total rescue numbers are included in the total number of rescues in any given year. For
213 reasons similar to primary cause reporting, if the total number of reported rescues for a given

year is compared to the total number in which rip currents were identified as the primary cause, without factoring out those agencies that serve beaches without rip currents, then the proportion of rescues related to rip currents is further diluted.

A third challenge for reviewers of the USLA data is that some agencies oversee both surf and inland areas, but report totals of all rescues at both venues (and the underlying causes). One example is the city of San Diego, which reports thousands of rescues each year including some (albeit a small number) that occur in Mission Bay, which is a low energy estuarine environment with no surf conditions or rip currents. Similarly, California State Parks oversees lifeguards at both surf beaches and inland lakes (including reservoirs), including them all in a total number of rescues (and underlying causes).

In determining the percent of rescues attributable to rip currents at surf beaches, it is necessary to exclude rescue reports from agencies that do not identify the primary cause of the rescue and to exclude, to the greatest extent possible, rescue reports from inland areas where rip currents are not present. If these steps are not taken in data evaluation, the percent of rip current caused rescues will be misrepresented. Avoiding this misrepresentation requires both an in-depth review of the data and knowledge of which reporting agencies serve only inland areas. Even then, for the hybrid agencies that cover both inland and surf, it is not possible to exclude the inland rescue data, because it is not separately reported. A goal of this study is to attempt to eliminate factors in the USLA rescue dataset that artificially under-represent the impact of rip currents on rescues and drowning.

3. Methodology

Analysis of USLA rescue data was restricted to the most recent 20 years of compiled data from 1997 to 2016. Data was first checked and corrected for any errors and anomalies. For example, there were several isolated examples where data from one agency appeared twice in a given year, and in a few other cases, the total addition of yearly rescues was found to be mathematically incorrect. These turned out to be minor and did not affect the overall data outputs significantly.

As a typical example, a double reporting of data by an agency in 2002 increased the total number of rescues by 10, but this was only 0.021% of the total number of rescues in the year.

The dataset was then culled using objective decision rules. Specifically, as the purpose was to examine rip current rescues on surf beaches, rescue data from any agency overseeing a body of water that did not include surf beaches was removed. Great Lakes beaches were left in the dataset because they are large enough to generate surf and rip currents under certain meteorological conditions, although reporting from the Great Lakes, which included the city of Chicago in early periods of the dataset, is presently minimal.

Any agency that did not report a primary cause of rescues was also removed. This, unfortunately, resulted in removal of the entire dataset of Los Angeles County, which normally reports the largest number of rescues of any beach agency. It was found that in a typical year this is more than 15% of all rescues reported to the USLA. However, a random sampling of agencies reporting in Orange County (to the immediate south of Los Angeles County) found rip currents to be the primary cause in 83% of rescues from drowning. This is comparable to all West Coast agencies, so it appears likely that if Los Angeles County were to report, it would report similar values.

Figure 1 shows the total number of agencies reporting for each year and the excluded agencies (those with no primary cause being reported or non-surf beach agencies). Agencies with both surf and non-surf beaches were included if they reported a primary cause, despite the inevitable, unknown degree of overall dilution of rip currents as a primary cause. Any reports of rescues due to the cause ‘swiftwater rescue’ were removed from consideration since, by definition, they do not occur at surf beaches. In general, the number of included surf agencies that report primary cause has increased over time, while the number of excluded agencies has remained relatively constant (Figure 1).

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-143
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 25 June 2018

Natural Hazards and Earth System Sciences
Discussions

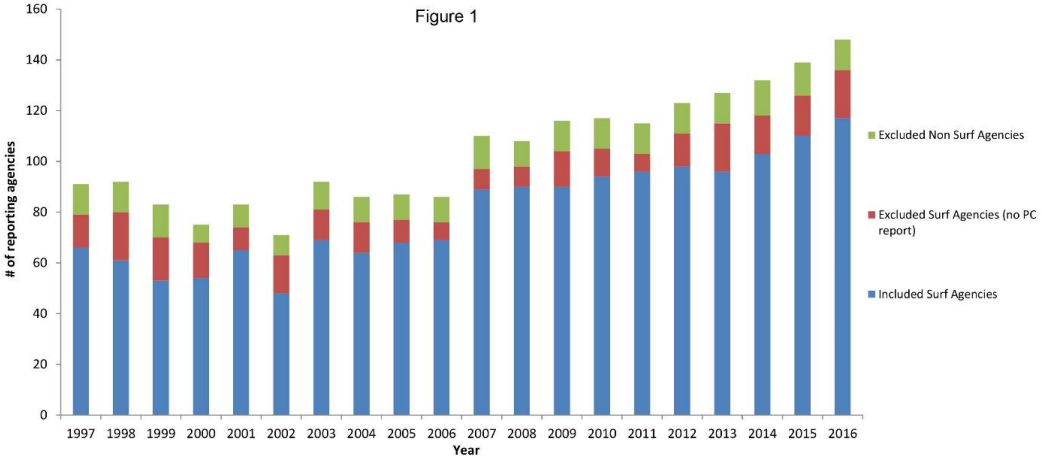


Figure 1. The number of lifeguard agencies reporting to the United States Lifesaving Association statistic database between 1997-2016. Included surf agencies report primary cause of rescues (PC).

Where 'scuba' was listed as a primary cause, the rescues were included, as these rescues can and do take place in surf environments. In these cases, as in others, the primary cause is up to the determination of the reporting rescuer. That is, for example, a scuba diver may be rescued due to complications from scuba diving, or from being caught in a rip current, or both. The primary cause is what is to be reported and what we rely on here.

4. Results and Discussion

Primary causes of surf beach rescues conducted for the period 1997-2016 for all included reporting agencies in the U.S. were geographically separated into East, West, and Gulf coasts, as well as the Hawaiian Islands (Table 1). The Great Lakes were not included because no agency from the Great Lakes reported a primary cause. In general, the percent of rescues caused by distress due to rip currents ranged from 75.3% (East Coast) to 84.7% (West Coast) with a long-term average across all regions of 81.9% (Table 1). Figure 2a shows the gross reporting of primary cause rescues for included agencies during the period 1997-2016 and while the number of rescues for all primary causes clearly fluctuates temporally, as evident in Figure 2b this is largely due to the increase in reporting lifeguard agencies over this time. As also evident in

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-143
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 25 June 2018

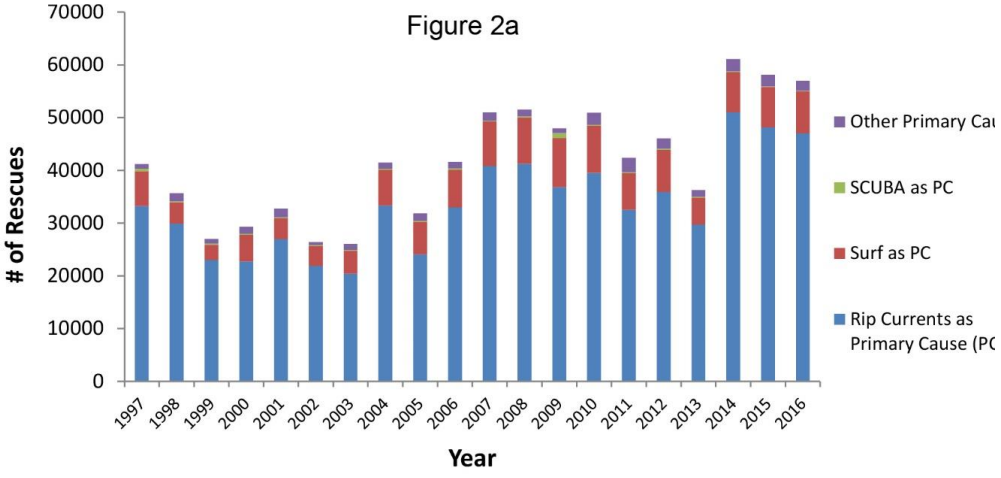
293 Figure 2b, the percentage of total rip current rescues as the primary cause of all rescues
294 nationally varies annually from 75.7% (2005) to 85.1% (1999) with no clear temporal trend
295 apparent. There are many factors involved that can impact the number of rip current rescues that
296 occur in a given year including weather conditions, surf conditions, number of rip currents
297 present, and beach visitation numbers. However, overall, even if the rip rescue data is normalized
298 by the number of reporting lifeguard agencies, the number of surf rescues attributable to rip
299 currents does not vary greatly over time.
300

Table 1

Region/Rescues	All	Rip Current	Surf	Scuba	Other
East Coast	233,167	175,572 (*75.3*)	50,135 (*21.5*)	227 (*0.1*)	7,233 (*3.1*)
West Coast	608,041	514,935 (*84.7*)	65,349 (*10.7*)	4,288 (*0.7*)	23,469 (*3.9*)
Gulf Coast	15,154	11,876 (*78.4*)	3,157 (*20.8*)	16 (*0.1*)	105 (*0.7*)
Hawaiian Islands	47,191	37,632 (*79.7*)	7,262 (*15.5*)	150 (*0.3*)	2,147 (*4.5*)
TOTAL	903,553	740,015 (*81.9*)	125,903 (*13.9*)	4,681 (*0.5*)	322,954 (*3.6*)

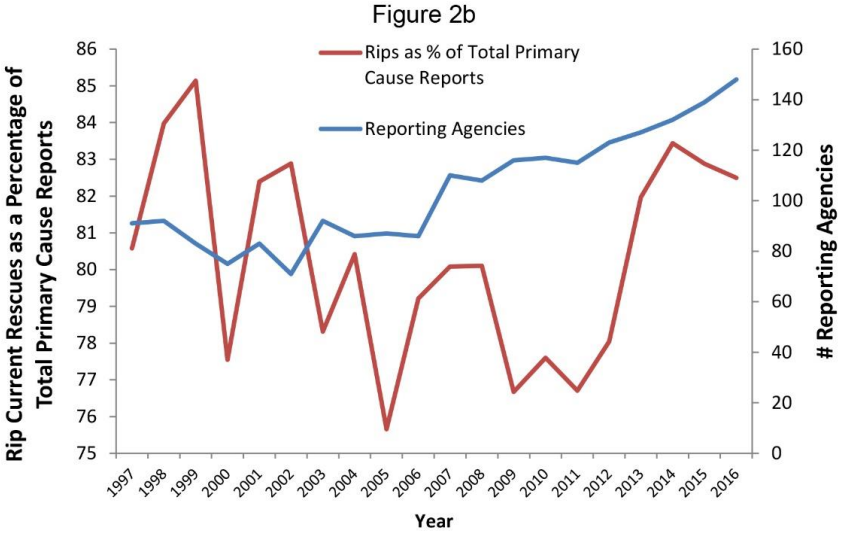
301 Table 1: Primary causes of rescues on surf beaches reported to the USLA
302 statistic database 1997-2016 by coastal region in the U.S. The percent of rescues
303 by primary cause are indicated in parentheses. The Great Lakes are not included
304 as no lifeguard agency in that region reports primary cause.

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-143
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 25 June 2018



305

306 Figure 2. a) Total rescues reported to the USLA by primary cause over the period
307 1997-2016.



308 Figure 2. b) Percentage of rip current rescues as primary cause and the number of
309 lifeguard reporting agencies to the USLA over the period 1997-2016.

310

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-143
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 25 June 2018

311 **4.1 Under-estimating rip current rescues**

312 Brighton et al (2013) reviewed a smaller cohort of USLA data (2005 – 2011) and determined that
313 only 53.7% of rescues were related to rip currents, which is significantly lower to the estimates
314 derived here. The difference can be attributed to Brighton et al. (2013) using gross rescue totals
315 in the USLA data, without excluding agencies that did not report a primary cause, agencies at
316 beaches without surf, and swiftwater rescues. Examining the same data in this way yields a result
317 of 54.9%, which is very close to the value reported by Brighton et al. (2013) and suggests that
318 their estimate significantly underestimates the percent of rescues attributable to rip currents in
319 the U.S.
320
321 Another aspect of the data reporting by Brighton et al. (2013) reveals some of the challenges
322 involved in the reporting of rip current rescues in general. In reviewing Australian lifeguard and
323 lifesaver rescue data provided by Surf Life Saving Australia (SLSA), Brighton et al. (2013)
324 found that just 57.4% were attributable to rip currents. While they removed rescue reports
325 "known to be in areas unaffected by rips" (as done in our study), they were only able to report on
326 data relating to "major rescues", which are cases where "treatment is required" post-rescue and
327 only make up 1.4% of all rescues reported by SLSA. The reason for this is that these were the
328 only incidents in the dataset where a primary cause of rescue was reported. Thus, they represent
329 unusual and extreme cases and likely also greatly underestimate the actual percentage of rescues
330 on Australian surf beaches caused by rip currents. Of note, the U.S. data from agencies reporting
331 a primary cause includes 100% of rescues, whether major or routine.
332
333 Other discrepancies involving the USLA dataset set are presented in Gensini and Ashley (2010b)
334 who reviewed data for the years (2000 – 2009) and suggested that only 36.5% of rescues on U.S.
335 beaches were attributed to rip currents, which is less than half of the 75-84% range reported here.
336 We reviewed the data published on our website for these same years. Even when using gross
337 data, without excluding data from agencies that did not report a primary cause and agencies from
338 areas serving areas without surf, we found that 53% would appear to be attributable to rip
339 currents, which is similar to the value reported by Brighton et al. (2013) for overlapping years.
340 We then reviewed all of the years of USLA data for our study period without correcting for
341 agencies that did not report a primary cause of the rescue and agencies at beaches without surf.

342 The percent of rescues related to rip currents was found to be 49%. This is quite similar to the
343 conclusions of Brighton et al, but significantly higher than that of Gensini and Ashley (2010b)
344 and it remains uncertain how their value of 36.5% was attained.
345
346 **4.2 Rip current rescues and fatalities**
347 As described in the Introduction, some discrepancy also exists regarding estimates of annual
348 average rip current related drowning fatalities in the U.S., with values ranging from 35 (Gensini
349 and Ashley, 2009) to more than 100 (USLA, 2004) to 150 (Lushine, 1991). It is important to
350 note that all of these values are estimates as there is no U.S. national database for surf beach
351 drowning fatalities, which is also a global problem due to the overall lack of accurate and
352 consistent incident reporting. It was noted earlier that the USLA has theorized the percent of
353 rescues from drowning in rip currents as a proxy for the percentage of drowning deaths at surf
354 beaches in the absence of rescue.
355
356 To examine the approach of relying solely on USLA data for rip current drowning estimates, we
357 reviewed the most recent full calendar year of fatal drowning reports from surf beach lifeguard
358 agencies to the USLA (2016). There were 128 surf beach lifeguard agencies that reported a total
359 of 77 drowning deaths in unguarded areas within their jurisdictions (areas where and when
360 lifeguards were not present) and 22 drowning deaths in guarded areas (areas with lifeguards on
361 duty) for a total of 99 drowning deaths in calendar year 2016. If we apply the long-term national
362 average of 81.9% of rip current related rescues (Table 1) to that value, it can be hypothesized
363 that 81 deaths were likely due to rip currents in the jurisdictions of the reporting lifeguard
364 agencies. Importantly, the number of reporting lifeguard agencies come nowhere near covering
365 the breadth of all the surf beaches in the U.S. and many are staffed (and report) only in summer
366 months. Using the assumption that rip current related rescues are a proxy for rip related
367 drowning fatalities, the USLA estimate of more than 100 per year seems well-justified, if not an
368 under-estimate.
369
370 The authors note that the U.S. National Weather Service recently began posting reports of U.S.
371 "surf zone fatalities" at: https://www.weather.gov/safety/ripcurrent-fatalities17. The sources of
372 the data are not identified on the NWS website, so we cannot comment on the reliability of the

data. The website states, "Accurately tracking these types of fatalities is difficult because so many go unreported and undocumented." The data includes an annual average number of rip current related drowning fatalities between 2013-2017 of 62 fatalities per year. This would again suggest that the actual number is closer to the USLA estimate.

4.3 Limitations and value of the USLA dataset

There are clear limitations in the USLA data, some of which have been described here previously. Not all surf beach lifeguard agencies in the U.S. report rescue data to the USLA and some that do report do not report a primary cause. As well, the dataset is limited in that it cannot be demonstrated to represent a proportional exposure, on a per visitor basis, to rip currents on all beaches of the US. We therefore agree with Brighton et al. (2013) that the collection of drowning data using consistent categories and the routine collection of rip current information will allow for more accurate global comparisons. If beach lifeguard agencies worldwide used consistent reporting data points and reported on the primary cause, including rip currents, for all rescues, beach safety practitioners would be better able to determine the impact of the rip current hazard globally and develop public awareness and education strategies accordingly (Houser et al., 2017). This is certainly true of the surf beach reporting situation in the United States.

The value of the USLA data is that it is the largest single repository in the world of data related to causation of distress at surf beaches. For example, an average of 80,002 rescues from drowning per year were reported to the USLA over the five-year period 2012 -2016, for a total of 415,014 rescues, most with a primary cause denoted. While the USLA has shared this data publicly, this study has shown that without a full understanding of the individual, underlying data sources, researchers may have difficulty making necessary and accurate conclusions. In response to values reported in previous studies, it is hoped that this study now provides a more clear representation of the USLA dataset in regards to the rip current hazard.

5. Conclusions

An examination of rescue data reported by surf lifeguards in the United States to the United States Lifesaving Association has shown that rip currents are the primary cause of between 75.3-

84.7% of all surf rescues on regional American beaches, a significantly higher estimate than previously reported in the scientific literature. Using the percentage of rip current caused rescues as a proxy to estimate the number of annual drowning deaths attributable to rip currents in the U.S. suggests that an annual figure of over 100 is not unreasonable, particularly as it is based on actual reports of beach lifeguard agencies. Regardless of the limitations of this approach, it is clear that the United States is in need of an improved and consistent approach amongst all lifeguard agencies to report surf related rescues by primary cause. It is vital to develop accurate estimates of both rip current related rescues and drowning deaths so that local governments, public policymakers, tourism authorities, public health professionals, and funders of mitigation measures understand that rip currents are by far the greatest health hazard related to those entering the water at surf beaches. Through this awareness, appropriate resources such as the provision of additional lifeguard services and development of public education programs can be justified and implemented to assist in drowning prevention.

Data availability. This work relied entirely on data published in a publicly available database by the United States Lifesaving Association on its website at: www.usla.org.

Competing interests. B. Chris Brewster is a long-time volunteer official with the United States Lifesaving Association in various unpaid positions. Rick Gould is a long-time volunteer official with the United States Lifesaving Association, primarily overseeing the gathering and publication of the statistics referenced herein. Rob Brander declares that he has no conflict of interest.

References

Arozarena, I., Houser, C., Echeverria, A. G., and Brannstrom, C.: The rip current hazard in Costa Rica, Nat. Hazards, 77, 753–768, 2015.

Attard, A., Brander, R.W., and Shaw, W.S.: Rescues conducted by surfers on Australian beaches. Accident Anal. Prev., 82, 70–78, 2015.

Branche, C.M. and Stewart, S. (Eds.): Lifeguard effectiveness: A report of the working group, Atlanta: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, 2001.

437 Brander, R.W. and Scott, T.: Science of the rip current hazard, in: The Science of Beach
438 Lifeguarding: Principles and Practice, CRC Press, Boca Raton, 67–85, 2016.

439 Brannstrom, C., Trimble, S., Santos, A., Brown, H.L., and Houser, C.: Perception of the rip
440 current hazard on Galveston Island and North Padre Island, Texas, USA. Nat Hazards, 72,1123–
441 1138, 2014.
442
443 Brewster, B.C.: Rip current misunderstandings. Nat Hazards, 55(2), 161–162, 2010.
444
445 Brewster, B.C. and Gould, R.: Comment on "Rip current related drowning deaths and rescues in
446 Australia 2004-2011" by Brighton et al. (2013). Nat Hazards Earth Sys, 2, 2761–2763, 2014.
447
448 Brighton, B., Sherker, S., Brander, R.W., Thompson, M., and Bradstreet, A.: Rip current related
449 drowning deaths and rescues in Australia 2004–2011, Nat Hazards Earth Sys, 13, 1069–1075,
450 2013.
451
452 Castelle, B., Scott, T., Brander, R.W., and McCarroll, R.J.: Rip current types, circulation and
453 hazard. Earth Sci. Rev., 163, 1–21, 2016a.
454
455 Castelle, B., McCaroll, R.J., Brander, R.W., Scott, T., and Dubarbier, B. Modelling the
456 alongshore variability of optimum rip current escape strategies on a multiple rip-channelled
457 beach. Nat Hazards, 81(1), 664–686, 2016b.
458
459 Gensini, V. and Ashley, W.: An examination of rip current fatalities in the United States, Nat
460 Hazards, 54, 159–75, 2010a.
461
462 Gensini, V. and Ashley, W.: Reply to "Rip Current Misunderstandings" (Short Communication),
463 Nat Hazards, 55, 163–165, 2010b.
464
465 Hatfield, J., Williamson, A., Sherker, S., Brander, R.W., and Hayen A.: Development and
466 evaluation of an intervention to reduce rip current related beach drowning. Accident Anal. Prev.,
467 46, 45–51, 2012.
468
469 Houser, C., Trimble, S., Brander, R.W., Brewster, B., Dusek, G., Jones, D., and Kuhn, J.: Public
470 perceptions of a rip current hazard education program: "Break the Grip of the Rip!", Nat Hazards
471 Earth Sys., 17, 1003–1024, 2017
472
473 Klein, A., Santana, C., Diehl, E., and De Menezes, J.: An analysis of hazards associated with sea
474 bathing: Results of five years work in oceanic beaches of Santa Catarina State, southern Brazil, J.
475 Coastal Res., SI 35, 107–116, 2003.
476
477 Lushine, J. B.: A study of rip current drownings and related weather factors, Natl Weather
478 Digest, 16(3), 13–19, 1991.
479
480 MacMahan, J., Thornton, E., and Reniers, A.: Rip current review, Coast. Eng., 53, 191–208,
481 2006.
482

McCarroll, R.J., Brander, R.W, Macmahan, J.H., Turner, I.L., Reniers, A.J.H.M., Brown, J., Bradstreet, A., and Sherker, S.: Evaluation of swimmer-based rip current escape strategies. Nat Hazards, 71, 1821–1846, 2014.

Moulton, M., Dusek, G., Elgar, S., and Raubenheimer, B.: Comparison of rip current hazard likelihood forecasts with observed rip current speeds. Weather Forecast, 32, 1659–1666, 2017.

Scott, T., Masselink, G., Austin, M.J., and Russell, P.: Controls on macrotidal rip current circulation and hazard. Geomorphology, 214, 198–215, 2014.

Surf Life Saving Australia (SLSA): *National Coastal Safety Report 2015*. Sydney: Surf Life Saving Australia, 2017.

United States Lifesaving Association (USLA), 2004. Letter to National Weather Service 13 April, 2004.

United States Lifesaving Association (USLA): Open Water Lifesaving — The United States Lifesaving Manual, 3rd Edition, Huntington Beach, California, 2017.

United States Lifesaving Association (USLA): www.usla.org, last access 14 February 2018a.

United States Lifesaving Association (USLA): www.usla.org/statistics, last access 14 February 2018b.