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# The rip current hazard in Costa Rica

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**Abstract** Deaths from rip currents are a major hazard on global beaches, but few data are available at a national scale to support the development of appropriate intervention programs. Analysis of data from the Judicial Investigation Organization of Costa Rica indicates that drowning is the leading cause of violent death in the country, with 1,391 drownings between 2001 and 2012. Approximately 590 of those drownings occurred in a marine environment and are listed as being the result of rip currents. A majority (64 %) of the drownings attributed to rip currents involved victims from Costa Rica and tended to involve young single male students at beaches within a relatively short drive from San Jose on weekends and on national holidays. In comparison, the majority of foreign drowning victims were older males from the USA and Nicaragua with no statistically significant variation in the number of those drownings by day of the week. Predicted wave forcing and measured sediment characteristics suggest that the majority of drownings are associated with a transverse bar and rip (TBR) morphology with quasi-steady rip channels close to the beach. The interannual variation in both local and foreign drownings exhibits a statistically significant dependency on the variation in wave height with the Pacific-North American (PNA) Oscillation. Specifically, drownings peak during the negative phase of the PNA when wave heights are significantly smaller, which may reflect a tendency for beach users to enter calm water when the beach tends to have a TBR morphology. Further study is required to characterize the rip hazard at the most popular beaches on the Pacific and Caribbean coasts and to determine the level of rip knowledge by both local and foreign beach users.

**Keywords** Rip current · Drownings · Pacific-North America Oscillation · Costa Rica

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## 1 Introduction

Rip currents are narrow seaward-flowing currents that represent a significant hazard to beach users around the world (e.g., Klein et al. 2003; Sherker et al. 2008; Scott et al. 2009; Gensini and Ashley 2010; Houser et al. 2011a, b; Brander et al. 2011; Barrett and Houser 2012; Brighton et al. 2013). Capable of transporting experienced swimmers a significant distance offshore, rip currents are a particular threat to inexperienced and uninformed beach users. In Australia, drownings tend to be related to alcohol consumption, gender, age, overconfidence in swimming ability, and the inability of beach users to spot a rip current (Morgan et al. 2009). A survey of beach users on three heavily used public beaches in Texas found that only 13 % of respondents were able to correctly identify a rip current in a photograph (Brannstrom et al. 2014, 2015) consistent with an earlier study from Florida (Caldwell et al. 2013). As a consequence, even experienced swimmers can be unexpectedly caught in a rip and can even drown if they panic and become exhausted fighting against the current (Brander et al. 2011).

Since drownings can have a significant social and economic impact on a recreational beach, rip currents should be recognized as a major health problem (Short and Hogan 1994). It is estimated that rip currents are responsible for almost 90 % of surf rescues in Australia (Short and Hogan 1994) and between 40 and 50 drownings per year (Sherker et al. 2010; Brighton et al. 2013). A reanalysis of the National Coronial Information System of Australia by Brighton et al. (2013) suggests that the number of rip current drownings is only 21 per year. Gensini and Ashley (2010) estimate that only 30–40 individuals drown each year as a result of being caught in a rip current, far fewer than the 150/year estimated by Lushine (1991). The discrepancy in the estimates from both Australia and the USA is a reflection of the decentralized nature of mortality record keeping (particularly in the USA) and the speculative and anecdotal information that is difficult to trust, or misattribution of drownings to inexperience or out of depth (Brighton et al. 2013). Similar problems confound estimates of rip-related rescues, particularly since more than 83 % of rip current survivors report being able to escape the rip without assistance from a lifeguard and are therefore not recorded in official statistics (Drozdzewski et al. 2012). In this respect, Brighton et al. (2013) argue that the rip current hazard is largely underestimated, which can have significant impact on available funding to support lifeguards and other lifesaving services. While there may be some concern that warning signs and lifeguards may give beach users a perception that a certain beach is relatively dangerous, it is reasonable to expect that the lifeless body of a drowning victim and publicity of the event would have a far greater impact on beach user perception.

Outside of the USA and Australia, major knowledge gaps exist relating to the number of rip rescues and drownings. For example, no published study estimates the number of rip-related drownings in Central America, where many tourists from the USA, Canada, and Europe spend their vacations on the beach. Rip-related drownings in Costa Rica have caught the attention of the media since major drowning events in 1978 and 1987: "The 'right to drown' too easily exercised" (Tico Times, March 22, 1978) and "Rips of death" (La Nación, September 30, 1987). A 1998 article in La Nación (also titled "Rips of death") was first to show that the number of drowning deaths was nearly triple that of automobile accidents. In recent years, there have been a number of highly publicized foreign drownings in Costa Rica, including the 2011 drowning of three teenagers at Playa Bejuco on the central Pacific coast (The Columbus Dispatch, May 7, 2011). These students were on a mission trip that included visits to an orphanage, drug rehabilitation center, and some local villages and decided to visit a beach on a free day before heading back to the USA.

Playa Bejuco is not a popular beach for tourists, and although there are warning signs indicating that rip currents pose a hazard on this beach, an unsuspecting bus driver from outside the region brought the students to the beach. In 2006, three students and a teacher on a Spanish immersion trip from Kansas were swept offshore and drowned in the heavy surf at Playa Palo Seco, a beach lacking lifeguards and only 10.5 km south of Bejuco (Lawrence Journal World, June 13, 2006). The number of drownings in January 2013 at nearby Playa Esterillos was equivalent to the number of drownings in all of 2012 leading to a call for lifeguards in La Nación (January 28, 2013): "Neighbors launch alert voice for drownings in Esterillos Beach." After 49 rescues and seven drowning deaths during the Easter holiday, La Nación published another rip article ("Easter Sunday stunned by calm"; April 2014) to highlight the dangers of rip currents and recognize rips as a major health concern. Despite continued attention on rip currents in Costa Rica along with increased signage and the distribution of warning materials, there has been no appreciable decrease in the number of rip drownings.

Lifeguards are only present at three beaches in the Costa Rica, although some beaches occasionally employ lifeguards during busy holiday periods. The only beaches with permanent lifeguards are Playa Cocles in the South Caribbean, Playa Jacó in the Central Pacific (the most popular beach in the country) and Playa Blanca inside a private resort on the Central Pacific (Fig. 1). The community-supported lifeguard program at Playa Cocles was established in 2004 after five people drowned in 8 days, and there have been no drownings since the lifeguard program was established. However, it can be difficult to maintain a community-supported lifeguard program. The lifeguard program at Playa Tamarindo, one of the most popular beaches for tourists from the USA, was dismantled after the Association for Improving Tamarindo could no longer pay the lifeguard salaries (La Nación, October 1, 2007). No drownings were reported over the 3 years that the tower and team of lifeguards were present on the beach, but since 2007 there have been three (one in 2008, two in 2009) drownings at Playa Tamarindo.

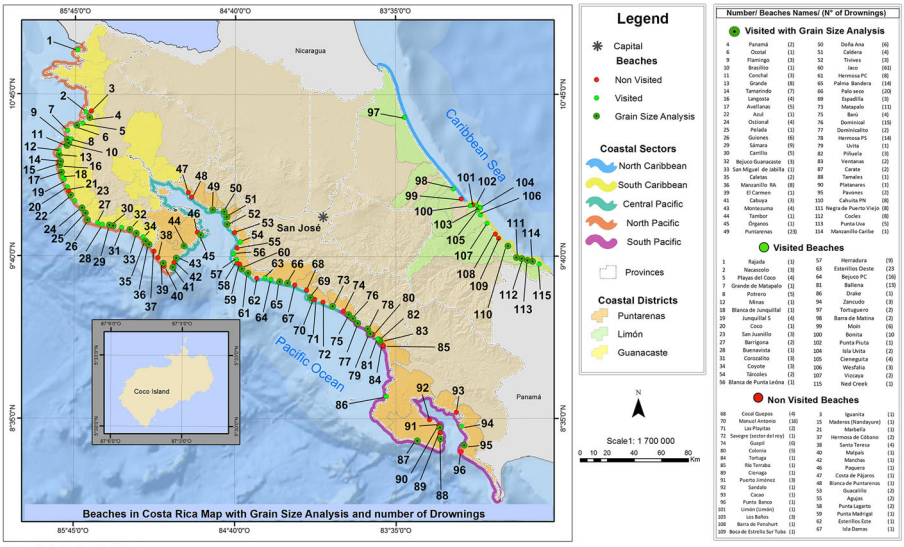


**Fig. 1** Costa Rica showing major beaches within the five coastal sectors and three coastal districts of the Pacific and Caribbean coasts

While few beaches have lifeguards, virtually every beach in the country has a rip current warning sign in both Spanish and English (Fig. 2a) and many beaches have a modified version of the NOAA sign that explains how to escape from a rip (Fig. 2b). It is reasonable to expect that many beach users (both tourists and locals) do not pay heed to the warning signs and without lifeguards present can get into trouble relatively quickly. Informal estimates that 200 people drown each year in Costa Rica are commonly cited in the media (The Columbus Dispatch, May 7, 2011). These estimates are based on speculation and anecdotal information and do not include data collected by the Judicial Investigation Organization. The purpose of this study is to provide the first estimates of the number of rip-related drownings in Costa Rica from 2001 to 2013 using data maintained by the Judicial Investigation Organization.

## 2 Study site

Costa Rica, a major international destination for sun-sand, ecological, and medical tourism (Matarrita-Cascante et al. 2010; Warf 2010; Van Noorloos 2011; Nost 2013), has ~1,228 km of coast with ~1,016 km of Pacific coast and 200 km of Caribbean coast. For the purposes of this study, the coast is divided into five geographical regions based on both geology and oceanography: North Caribbean, South Caribbean, North Pacific, Central Pacific, and South Pacific (Fig. 1). The North Caribbean coast stretches from the Nicaraguan border to north of Limón City and is characterized by oblique slip along steeply dipping faults of the Central Costa Rica deformed belt (Denyer et al. 1994). The resulting lowlands are composed of a sequence of huge alluvial fans incised by modern rivers,


**Fig. 2** Photographs of rip current warning signs posted at most beaches in Costa Rica. Shown are a common sign in both Spanish and English (**a**), modified versions of the USA NOAA sign that explains how to escape from a rip (**b**) and simple warning signs of danger currents (**c**)

covered by deep red, clay-rich soils. The narrow continental shelf and predominance of ground and wind swell from the ENE results in a strong longshore current responsible for the relatively long barrier beach that is only breached by the occasional river. Limited access to the beaches of the Northern Caribbean limits the number of locals and tourists using the beaches.

The Southern Caribbean region extends from Puerto Limón to Playa Gandoca and is characterized by uplifted reef platforms that create promontories at Limón City, and from Playa Cahuita to Playa Gandoca that segments the coast into a series of beaches of varying morphology and size. The rugged geomorphology of this region is controlled by active crustal shortening within the north Panama deformation belt along the Caribbean margin of the Panama block (Escalante and Astorga 1994). The relict coral and fringing reefs were lifted by 0.5–1.5 m during the 1991 M7.6 Valle de la Estrella earthquake (Denyer et al. 1994). The most visited beaches along the Caribbean coast are in the south near Cahuita (Grande and Negra de Cahuita, Cahuita, and Puerto Vargas) and between Puerto Viejo and Manzanillo (Cocles, Chiquita, Punta Uva, and Manzanillo). Due to the distance from San Jose and the lack of an international airport in the Southern Caribbean Region, fewer local and international tourists visit this section of coast compared with the Pacific coast (Nost 2013).

The Central Pacific Region extends from Cabo Blanco to Playa Barú and includes the Gulf of Nicoya. The Central Pacific is geologically and geomorphological distinct from the North and South Pacific regions. The coast in Central Pacific is characterized by differential Quaternary uplift rates owing to faults normal to the margin dissect the coast into several blocks with fluvial and marine terraces (Fisher et al. 1994, 1998). Whereas uplift in the north and south is infrequent but involves large displacements, uplift in the Central Pacific involves small but frequent earthquakes. As a consequence, the coast is fragmented into discrete blocks by faults perpendicular to the coast leading to relatively extensive beach systems broken by rocky promontories, although there are a number of smaller pocket beaches. Due to their close proximity to the Central Valley and San Jose, the beaches of the Central Pacific receive the greatest number of national and international visitors. The most popular beach is Jacó, which is only 1.5 h from San Jose and has a number of hotels, bars, restaurants, and other services for visitors. Other popular beaches in the Central Pacific are Playa Mantas, Playa Blanca (both near the Punta Leona-Herradura Promontory), Puntarenas, and Manuel Antonio. The latter beach is on the Quepos promontory and is the most visited National Park in the country.

The Northern Pacific region and Nicoya Peninsula are an emergent segment of the outer Chorotega forearc and are characterized by a narrow continental shelf and a steep and rocky coast. As a consequence, the coasts of Nicoya Peninsula are dominated by a rocky shore with abundant marine terraces and a raised platform indented with large bays (including Playas Salinas, Papagayo, and Tamarindo) and small pocket beaches (including Playa Samara and Playa Garza). The southernmost part of the Nicoya Peninsula is a very straight coast where open and exposed long beaches are common (Bejuco-Guanacaste, San Miguel de Jabilla, Guiones, Ostional, etc.). The most popular beaches in the North Pacific are Playas del Coco, Tamarindo, Flamingo, Samara, and Carrillo. The Osa Peninsula, in the South Pacific coast, is another emerged part of the outer Chorotega fore arc, and it is formed by rapid uplift and crustal shortening exactly over the central part of the Coco Ridge (Gardner et al. 1992). Similar to the Nicoya Peninsula, the Osa Peninsula is dominated by a number of small pocket beaches including Playa San Josecito, but also has more than 20 km long Corcovado beach (it is located inside de Corcovado National Park, and access is forbidden, for conservation purposes and for difficulty of evacuation in case

of puma, jaguar, or snake bite), Playa Carate, Playa Dominical, Playa Hermosa PS. In the South Pacific, the most popular beaches are Ballena, Piñuela, Uvita, and Hermosa PS. The growth of residential tourism and large-scale hotel development has been reported as an increasingly important phenomenon (Van Noorloos 2011).

## 3 Methodology

### 3.1 Mortality data

The Costa Rican Judicial Investigation Organization (OIJ; Organismo de Investigación Judicial) is the state organization charged with conducting investigations in cases of violent deaths of any kind. Since 2001, the agency has followed an exhaustive protocol for data collection that includes detailed geographical and personal information in addition to local authority documentation of the cause of death. Specifically, the OIJ has maintained records on the beach or coastal area where a drowning has occurred (or the cadaver was found) including province, county, and district as well as the sex, age, nationality of the victim. Only the district and not the specific beach was recorded in 2002, and in other years, the marital status, time of day, and occupation of the deceased were also recorded. It is important to note that the time and date may refer to the disappearance of the victim (if any witnesses were present), the finding of the corpse (potentially days later) or estimated by the forensic experts. This suggests that the data are not sufficiently accurate to be useful for tide level analysis. Before 2001, all drownings were coded the same and it is not possible to distinguish between drownings in pools, rivers, and the ocean. Therefore, the focus of this study is on drownings since 2001.

### 3.2 Oceanographic data

Each of the drownings since 2001 was compared with wave forecasts published by the University of Costa Rica. The Módulo de Información Oceanográfica owing to Centro de Investigaciones en Ciencias del Mar y Limnología (MIO-CIMAR) Web site (http://www.miocimar.ucr.ac.cr/manualmio) provides surf forecast for the next 7 days (two times per week) for the North Pacific, Central Pacific, South Pacific, Caribbean regions, and Coco Island. This information was extracted from numerical model forecasts for wind and swell using NOAA global data calculated by WAVEWATCH III model, at a distance of 30 km offshore. This deep-water forecast does not account for transformation as the waves approach the coast and change in height. Since 2011, the forecasts are provided for gust speeds, average wind speed, wind direction, maximum wave height, maximum and average wave height, wave period, and wave direction. Since 2011, predictions are available four times a day at 6 am, 12 am, 6 pm, and 12 pm. Between 2001 and 2011, forecasts are only available for the significant height and period. For the purposes of this study, we have converted all wave forecasts to significant wave heights assuming a Rayleigh distribution.

### 3.3 Beach state and nearshore morphology

Since 2010, we have visited 82 popular beaches that had the majority of observed drownings to conduct cross-shore surveys and collect sediment samples for grain size analyses. Profile sites were selected accounting for the most populated area of the beach,

and 200-g sand samples were taken in the same spot. These measurements allow us to calculate the surf similarity parameter for the beach on the day of drowning and all other days during the year. For all beaches, we calculated the surf similarity parameter used by Wright and Short (1984), which relates wave height with grain fall velocity and wave period:

$$\Omega = \frac{H_b}{\omega_S T} \quad (1)$$

where $H_b$ is the breaker height (m), $\omega_S$ is the settling velocity (m/s) of the sediment, and $T$ is the wave period (s). The settling velocity was calculated from the mean grain size using the model presented by Ferguson and Church (2004). In addition to beach profiling and grain size analyses of sand samples, a morphodynamic classification was completed using ground-based photographs and satellite imagery.

## 4 Results

There were 1,391 drownings ($\sim$115 per year) between 2001 and 2012, making drowning the leading cause of natural violent deaths in the country (Fig. 3). In comparison, the leading cause of violent death (including natural and accidental) was traffic accidents, with $\sim$120 deaths per year. A majority of the drownings (801) occurred in natural freshwater (lake, ponds, reservoirs, and rivers) environments; only 590 drownings were reported in marine environments. With the exception of falls, drowning in marine environments is responsible for more deaths per year than electrocution, suffocation, poisoning, shock, or animal bites.

Of the 590 drownings in a marine environment, 393 (64 %) were from Costa Rica and 223 (36 %) were classified as foreigner. As presented in Fig. 4, many of the foreigners who drowned were from the USA ($n = 96$; 43 % of foreign drownings), followed by visitors from Nicaragua ($n = 33$, 15 % of foreign drownings), Canada ($n = 16$, 7.2 % of foreign drownings), and Germany ($n = 11$; 4.9 % of foreign drownings). Other foreigners to drown were from the UK, Switzerland, and Italy. Although no data are available, we strongly suspect based on anecdotal information that most of the Costa Ricans who drowned were visitors from the San Jose area and are local to the coastal communities.

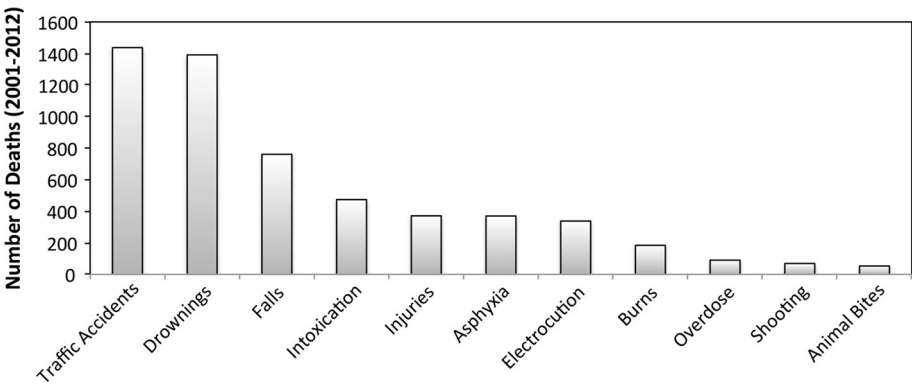


**Fig. 3** Number of violent deaths in Costa Rica between 2001 and 2012

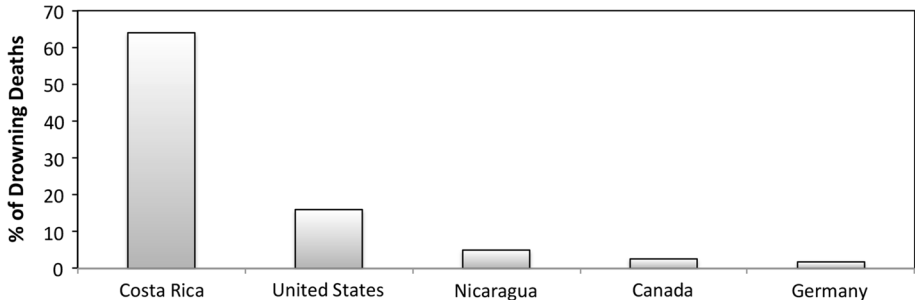


**Fig. 4** Distribution of drowning events (2001–2012) by nationality of the victim

Irrespective of nationality, the majority of drownings involved men ($n = 551$, 89 %) with only 65 drownings involving women (11 %). As shown in Fig. 5, drowning was typically associated with younger beach users, with 139 (23 %) drownings by beach users between 20 and 29 years of age. Beach users between 10 and 19 years accounted for 128 drownings (21 %), while beach users in their 30s account for 105 drownings (17 %). The majority of drowning victims were single ($n = 357$, 58 %; Fig. 6), consistent with the observation that the majority of drowning victims were young (Fig. 5) and students (Fig. 7). No statistically significant difference in age distribution was observed between men and women ($\chi = 1.2$; $\rho > 0.05$), but there is a statistically significant difference in the age distribution between local and foreign drowning victims ($\chi = 8.3$; $\rho < 0.01$). The average age of foreign drowning victims is 42 compared with an average age of 30 for local drowning victims.

## 4.1 Spatial variation

As presented in Fig. 8, the province with the largest number of drownings is Puntarenas in the Central Pacific, with 67 % of all drowning deaths observed followed by Guanacaste and Limón with 19 and 14 % of drownings between 2001 and 2012. At the district level, drownings in Guanacaste were concentrated in the districts of Tamarindo, Cabo Velas, Samara, Bejuco, and Cuajiniquil, with 15, 15, 10.3, 10.3, and 9.4 %, of drownings in this province. In the Province of Limón, the majority of drownings occurred in the districts of Cahuita and Limón, with 37.9 and 36.7 % of the number of drownings in this province,

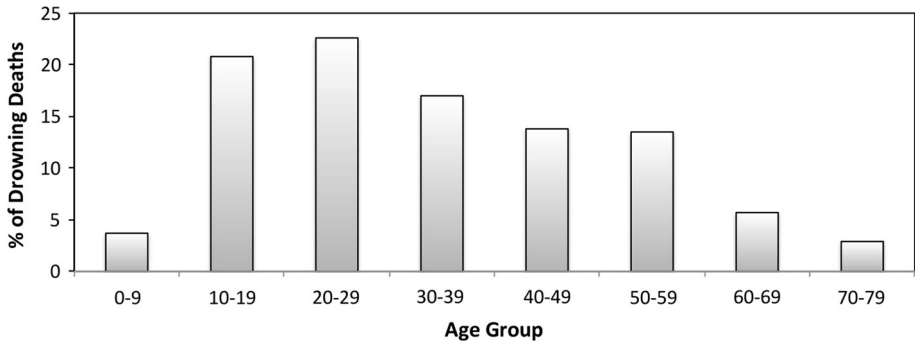


**Fig. 5** Distribution of drowning events (2001–2012) by age of victim

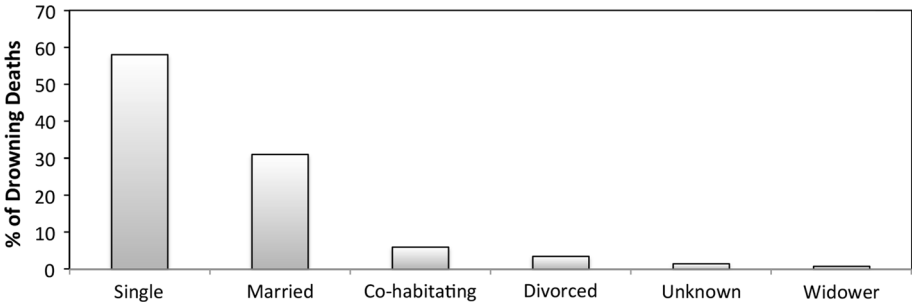


**Fig. 6** Distribution of drowning victims by marital status

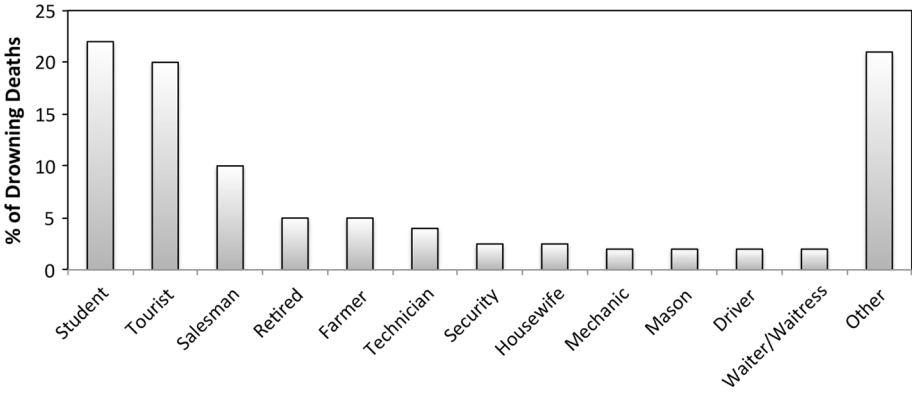


**Fig. 7** Distribution of drowning victims by occupation

respectively. In the Province of Puntarenas, drownings tended to be concentrated in the districts of Jacó, Parrita, and Quepos Bahía Ballena, with 19.2, 18, 13.8, and 8.3 % of the number of drowning of the Province of Puntarenas. The higher frequency of drownings in a particular region is associated with a greater than expected concentration of drownings at specific beaches. The 590 drownings that occurred between 2001 and 2012 occurred at only 139 beaches. The largest number of drownings ($n = 60$) occurred at Playa Jacó (25) followed by Esterillos West (24), Manuel Antonio (18), and Bejuco (17). The Caribbean beach with the largest number of recorded drownings was Playa Cocles with five drownings that occurred in 2004 before the local community established the lifeguard program.

### 4.2 Beach state

The distribution of drowning events with respect to wave heights and periods is shown in Fig. 9 for each geographical region relative to the total distribution of waves predicted in those regions. In both the Pacific and the Caribbean, the majority of drownings occur over a relatively narrow range of wave heights around 1.5 m. The primary difference between the coasts is the wave period, with most drownings on the Pacific coast associated with longer wave periods ($\sim$13 s) compared with the relatively short waves common on the Caribbean coast ($\sim$6 s). Grain size data are available for the 50 beaches that we visited

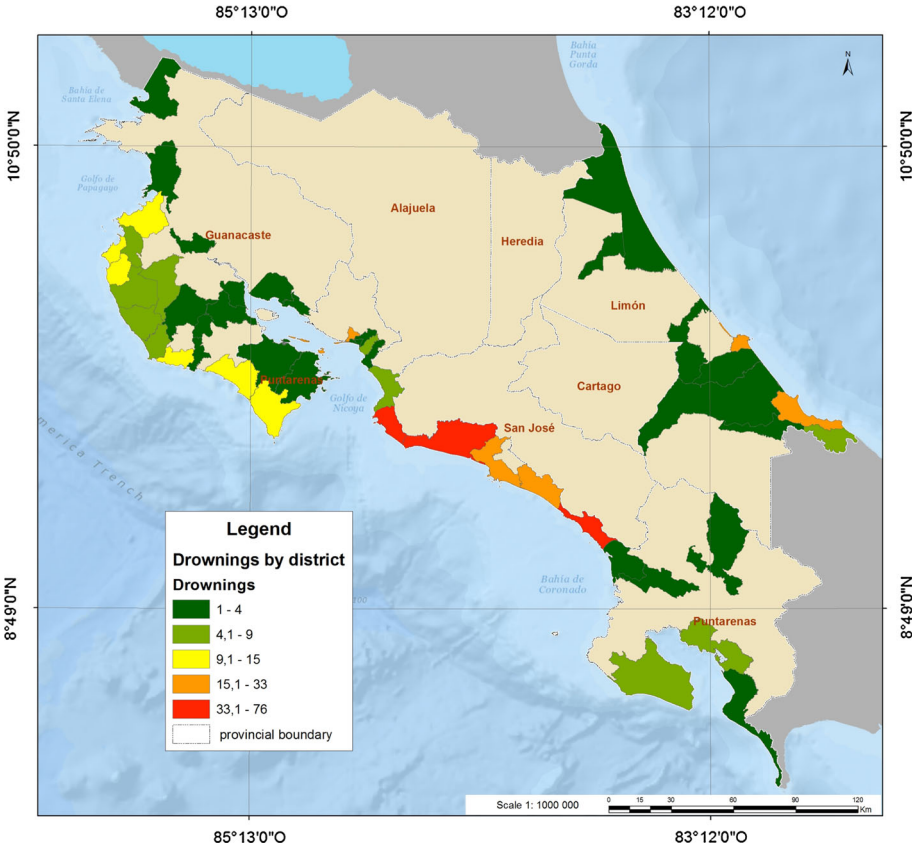


**Fig. 8** Distribution of drowning events by district

since 2010 associated with 448 of drownings. Using the wave height and period at the time of the drowning and the settling velocity, we calculated the surf similarity parameter (Eq. 1). A slight majority (56 %) of drowning events were observed on intermediate beaches ($1 < \Omega < 6$) that tend to be characterized by quasi-permanent rip channels (Fig. 10). The remaining drownings were observed on dissipative beaches (41 %), with only 3 % of drownings observed on reflective beaches.

## 4.3 Temporal variation

Most drownings are concentrated during April, January, February, and July, with 14.3, 13.5, 9.9, and 9.4 % of the total drownings, respectively (Fig. 11). Fewer drownings were observed in the months of November, September, and May, with 5.2, 5.2, and 5.6 % of drownings, respectively. The pattern is fairly similar between the Pacific and Caribbean coasts, suggesting that the within-year variation has more to do with visitations to the beach than oceanographic forcing. Within a given year, drowning by nationals is at a peak during the major holiday seasons of Christmas, Easter, and summer break, while drowning by foreign tourists is at a maximum during the months of July, December/January, and March (normally the spring break period for schools and universities in the USA).

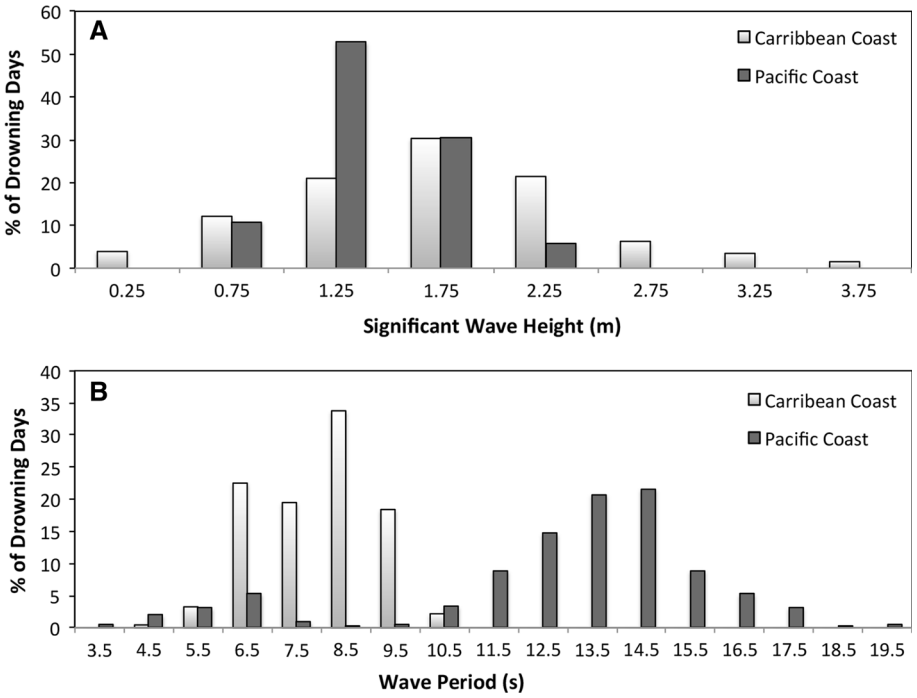


**Fig. 9** Distribution of drowning events by significant wave height and wave period (2001–2011), relative to the distribution of all predicted wave heights and period for each region

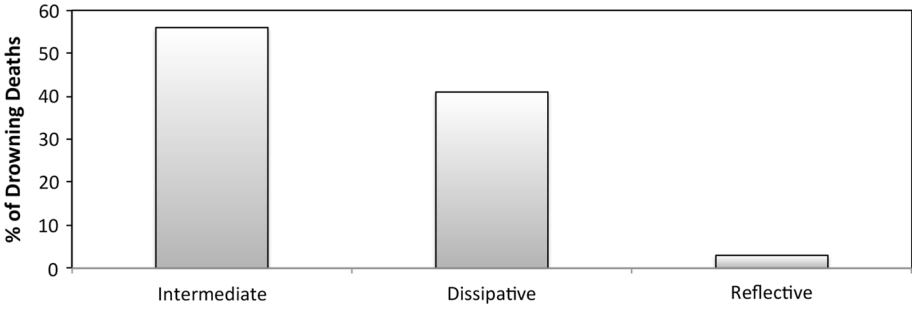


**Fig. 10** Distribution of drowning events based on surf similarity parameter

Drownings in both Guanacaste and the Central Pacific reach a maximum coincident with the Easter holiday, the month when significantly more locals drown than foreigners. Drownings also exhibit a distinct daily variation with a larger than expected number of drownings occurring on Saturdays and Sundays (Fig. 12) with a small peak on Mondays. The OIJ argues that the relatively large number of drownings on Mondays on the Pacific coast may be associated with the retrieval of drowning victims from the previous weekend. The increase in drownings on the weekend, however, is relatively weak on the Caribbean coast where a larger number of foreigners drown compared with the Pacific coast beaches

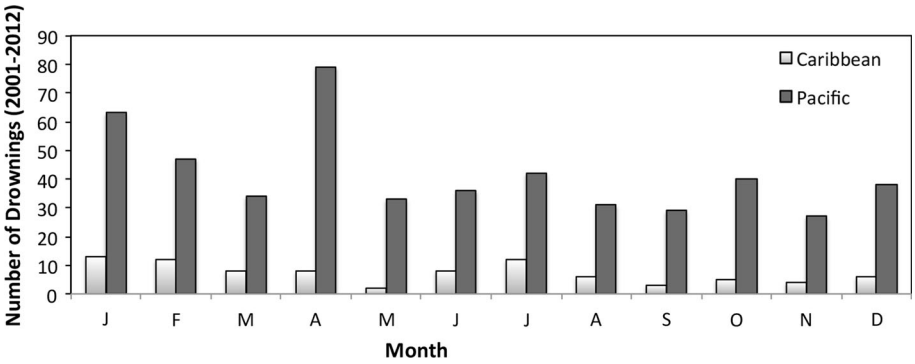


**Fig. 11** Distribution of drowning events by month for the Pacific and the Caribbean coasts

that are only a short distance ($\sim$1.5 h) from the Metropolitan area of San Jose and a popular destination for local tourists. This is consistent with the observation that drownings on Caribbean coast are at a peak in December/January and during the Easter holiday on the Pacific coast.

The interannual variation in drownings is presented in Fig. 13. Drownings were at a maximum in 2001, 2008, and 2009 when 69, 64, and 60 drownings were recorded, respectively. The fewest drownings were observed in 2005, 2012, and 2013 with 27, 31, and 35 drownings recorded, respectively. Drowning by foreigners was at a maximum in 2001, 2002, 2004, and 2009, while drowning by nationals was at a maximum in 2001, 2003, and 2008. The number of tourists has increased from 1,237,948 in 2004 to 2,343,213 in 2012, and a large number of tourists visit the beach at sometime during their stay in the country. There is no statistically significant correlation between the annual variation in foreign tourist drownings and the number of foreign visitors to the country ($\rho = 0.45$), and the interannual pattern in drownings is similar for both local and foreign visitors. This suggests that the interannual variation in drowning is a consequence of oceanographic and/or climatologic forcing, not the number of beach visits.

The drowning time series exhibits a periodicity of $\sim$2 years that suggests a connection between drownings and climate teleconnections. A comparison with the Southern Oscillation Index (SOI) suggests a tendency for more drownings during La Niña years.

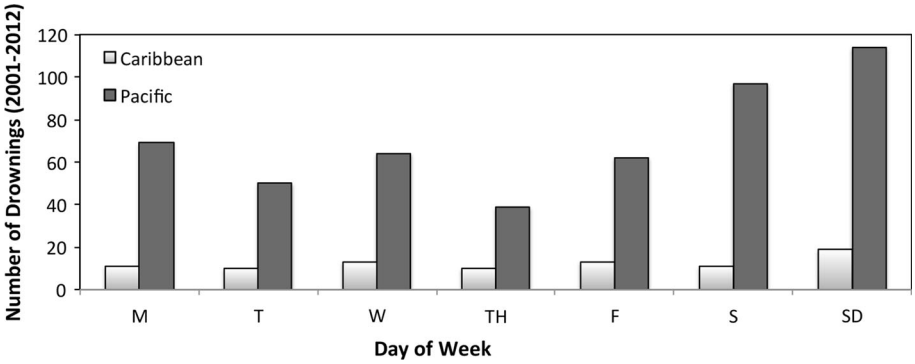


**Fig. 12** Distribution of drowning events by day of the week

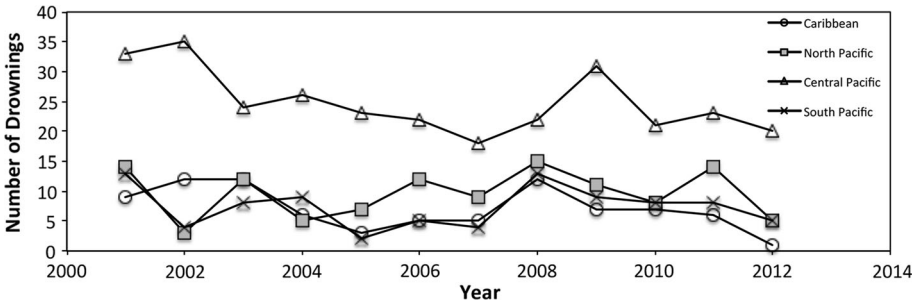


**Fig. 13** Interannual variation in drowning for all of Costa Rica

However, there is no statistically significant difference in the number of drownings between La Niña ($\sim$3.8 drownings per month) and El Niño ($\sim$3.4 drownings per month) at the 95 % confidence level. The interannual variation in drownings on both the Pacific coast exhibits a weak but statistically significant correlation with the Pacific-North American (PNA) Oscillation ($r^2 = 0.23$; $\rho = 0.04$). An average of four drownings per month is observed when the PNA index is $<-0.5$ compared with only two drownings per month when PNA $> 0.5$ ($t = 2.4$; $\rho = 0.02$). Interestingly, significant wave heights during a negative PNA are significantly smaller (at 1.2 m) compared with wave heights of $\sim$1.6 m during a positive PNA ($t = 2.6$; $\rho = 0.01$). No statistically significant difference was observed in the wave period between positive and negative phases of the PNA. As a consequence, there is a statistically significant difference in the surf similarity parameter between positive and negative phases of PNA. Beaches tend to be in a reflective to intermediate phase during negative phases of PNA compared with positive phases of PNA ($t = 4.6$; $\rho < 0.0001$).

## 5 Discussion

An analysis of data maintained by the Judicial Investigation Organization of Costa Rica suggests that rip currents are a major health problem, accounting for $\sim$51 deaths per year and more deaths than electrocution, suffocation, poisoning, shock, and animal bites. If all of these marine drownings are in fact associated with a rip current, then the drowning statistics suggest that the rip hazard in Costa Rica is comparable to the rip hazard in Australia (Sherker et al. 2010; Brighton et al. 2013) and the USA (Lushine 1991; Gensini and Ashley 2010). While the majority of drowning victims between 2001 and 2012 were from Costa Rica, 223 drowning victims ($\sim$19/year) involved foreign tourists primarily from the USA, Nicaragua, Canada, and Germany. Local drowning victims tend to be single male students between the ages of 20 and 29, consistent with Morgan et al. (2009) who found that drownings in Australia tend to be associated with gender and age in addition to alcohol consumption, overconfidence in swimming ability, and lack of rip knowledge. While the majority of foreign drowning victims were also men, drownings are most common for those aged 20–29 and 50–59, consistent with the demographics of the tourists. Based on recent surveys in Florida (Houser et al. 2011b; Caldwell et al. 2012) and Texas (Brannstrom et al. 2014), it is reasonable to expect that the majority of foreign drowning victims in Costa Rica had limited knowledge of rips and were unable to avoid the times

and locations that were most hazardous. This problem is made more acute by the lack of lifeguards on beaches in the country. In this respect, even experienced swimmers can be caught in a rip and can drown if they panic and become exhausted fighting against the current (Brander et al. 2011).

The larger number of Costa Ricans who drowned between 2001 and 2012 can be attributed to the greater frequency that residents are able to visit a local beach over the weekend and during holidays. It is reasonable to expect that the residents of San Jose and surrounding municipalities have a limited knowledge of the sea and weaker swimming skills, compared with those living at the coast and with regular access to the beach. This is consistent with anecdotal information provided by the lifeguards and surfers at Playa Jacó and explains why the largest number of drownings occurs in the Province of Puntarenas and specifically at Playa Jacó within 1.5 h of San Jose and with numerous hotels and tourist attractions. The wave forcing and morphology of this beach do not necessarily make it more dangerous than other beaches in Costa Rica. Rather, the larger number of drowning victims is a consequence of the larger number of beach users (both resident and foreign) and potentially a greater number of vulnerable beach users. Due to its close proximity, this beach is a popular destination for residents of San Jose during all holidays (Christmas, Easter, and summer break) and on weekends, compared with more distant beaches in the northwest and along the Caribbean coast. Drownings at these more distant beaches reach a peak during the Easter holiday along the Pacific coast and through December/January at Caribbean beaches, with the number of foreign drownings distributed throughout the year. Anecdotal evidence from residents of Playa Bejuco suggests that some of the foreign drownings may be the result of unsuspecting tourism operators from San Jose bringing clients to relatively dangerous beaches that receive few visitors and do not have a lifeguard present (see The Columbus Dispatch, May 7, 2011).

As noted, the annual variation in drownings is associated with the national vacation periods (January, April and July), which tend to be associated with relatively calm seas. During the fall and winter season, when the seas are rougher, there are fewer drownings because there are fewer people using the beach and tourism is at its lowest point of the year. This pattern is consistent with those observed in the USA (see Houser et al. 2011a, b) and suggests that the rip hazard is due to the beach user population and not oceanographic forcing. However, the interannual variation in drownings in Costa Rica does not exhibit a statistically significant relationship to the number of foreign visits, but varies in response to the Pacific-North American (PNA) Oscillation. Significant wave heights during a negative PNA are significantly smaller (at 1.2 m) compared with wave heights of $\sim$1.6 m during a positive PNA. It is not clear whether the increase in drownings with a negative PNA is a result of the conditions being more conducive to beach users entering the water (during calm conditions) and/or the beach exhibited a semipermanent rip channels close to the beach. The latter reason is consistent with the majority of drownings that are associated with a transverse bar and rip (TBR) morphology based on the predicted surf similarity parameter (see also Houser et al. 2011a, b). While the wave forcing is weaker during a negative PNA, the beach is characterized by a quasi-permanent rip channel that will be activated through low tide or in response to small increases in wave height (see Houser et al. 2013).

Further study is required to characterize the rip hazard at the most popular beaches on the Pacific and Caribbean coasts and to determine the level of rip knowledge by both local and foreign beach users. While there are geomorphological and personal reasons for the hazardous nature of Costa Rican beaches, the considerable number of drownings for such a small country can be attributed to the lack of lifeguards. The Caribbean beach with the

largest number of recorded drownings is Playa Cocles, with five drownings that occurred over 8 days in 2004, an event that prompted tourism-dependent business owners to establish a lifeguard station on the beach. There have been no recorded drownings on Playa Cocles since this action. Given the number of drownings on nearby beaches, it is reasonable to expect that the number of drownings on Cocles would have been far greater if the lifeguard station had not been established. While only three Costa Rican beaches have lifeguards, virtually every beach in the country has a rip current warning sign in both Spanish and English and many beaches have a modified version of the National Oceanographic and Atmospheric Administration (NOAA) sign that explains how to escape from a rip. However, it is not clear whether beach users, both foreign and resident, pay heed to the warning signs or can identify rip currents in the surf zone. While business owners may raise concern that warning signs and lifeguards may create the perception of a dangerous beach, the lifeless body of a drowning victim and the publicity of the drowning will likely lead to a negative perception of the beach as being dangerous. Recent media attention given to drownings in Costa Rica creates a negative perception that can have a negative economic impact on tourism-dependent business owners.

## 6 Conclusions

Analysis of data from the Judicial Investigation Organization of Costa Rica suggests that rip currents are a major health issue in Costa Rica accounting for 590 deaths between 2001 and 2012. A majority (64 %) of the drownings attributed to rip currents involved victims from Costa Rica and tended to involve young single male students at beaches within a relatively short drive from San Jose on the weekend and on national holidays. Within a given year, drowning by nationals is at a peak during the major holiday seasons of Christmas, Easter, and summer break, while drowning by foreign tourists is at a maximum during the months of July, December/January, and March. The interannual variation in both local and foreign drownings exhibits a statistically significant dependency on the variation in wave height with the Pacific-North American (PNA) Oscillation. Predicted wave forcing and measured sediment characteristics suggest that the majority of drownings are associated with a transverse bar and rip (TBR) morphology that develops during the negative phase of the PNA when wave heights are significantly smaller and beach users may be more confident in entering the water. While there are geomorphological and personal reasons for the hazardous nature of Costa Rican beaches, the considerable number of drownings for such a small country can be attributed to the lack of lifeguards.

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