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1 **Surf zone hazards and injuries on beaches in SW France**

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16

17 **Abstract**

18 Surf zone injuries (SZIs) are common worldwide, yet limited data is available for many geographical
19 regions, including Europe. This study provides the first preliminary overview of SZIs along
20 approximately 230 km of hazardous surf beaches in SW France during the summer season. A total of
21 2523 SZIs over 186 sample days during the summers of 2007, 2009 and 2015 were analysed.
22 Documented injury data included date and time; beach location; flag colour; outside/inside of the
23 bathing zone; age, gender, country and home postal code of the victim; activity; cause of injury; injury
24 type and severity. Injuries sustained ranged from mild contusion to fatal drowning, including severe
25 spinal injuries, wounds and luxation. While the most severe injuries (drowning) were related to rip
26 currents, a large number of SZIs occurred as a result of shore-break waves (44.6%; $n = 1125$) and surfing
27 activity (31.0%; $n = 783$) primarily inside and outside of lifeguard patrolled bathing zones, respectively.
28 Victims were primarily French living more than 40 km from the beach (75.9% of the reported
29 addresses; $n = 1729$), although a substantial number of victims originated from Europe (14.7% of the
30 addresses reported; $n = 335$), including The Netherlands (44.2%; $n = 148$), Germany (26.3%; $n = 88$) and
31 Belgium (12.5%; $n = 49$). The predominant age group involved in the incidents was between 10-25
32 years (54.5%; $n = 1376$) followed by 35-50 years (22.6%; $n = 570$), with the majority of SZIs involving
33 males (69.6%, $n = 1617$). Despite the large predominance (74.1%; $n = 33$) of males involved in the most
34 severe drowning incidents, all of which occurred outside the bathing zone, a surprisingly large
35 proportion of females (48.0%; $n = 133$) experienced milder drowning incidents involving only minor to
36 moderate respiratory impairment, peaking at 58.2% ($n = 85$) within the age group 10-25. The
37 spine/cervical injury population is very young, with 58.5% ($n = 313$) within the age group 10-20. Specific
38 injuries tended to occur in clusters (e.g. rip current drowning or shore-break injury) with particular
39 days prone to rip-current drowning or hazardous shore-break waves, suggesting the potential to
40 predict level of risk to beachgoers based on basic weather and marine conditions. This study calls for
41 increased social-based beach safety research in France and the development of more effective public
42 awareness campaigns to highlight the surf zone hazards, even within a supervised bathing zone. These
43 campaigns should be targeted towards young males and females, in order to reduce the number of
44 injuries and drownings occurring on beaches in SW France.

45

46 **Keywords:** surf zone hazards; drowning; spinal injuries; rip currents; shore break; surfing

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48

49 **1. Introduction**

50 Sandy beaches are an attractive and natural playground for the millions of people who visit them each
51 year worldwide. Beachgoers represent a diverse demographic group and visit beaches for a variety of
52 recreational activities including sun bathing, swimming and wading, bodyboarding and surfing (West,
53 2005). However, despite their attractive qualities, beaches can also be dangerous environments. This
54 is particularly true of beaches characterised by waves breaking at the shoreline and across a wide surf
55 zone, where dangerous wave conditions and strong currents pose a threat to those beachgoers
56 entering the water (Short and Brander, 2014; Short and Weir, 2016; Castelle et al., 2016a). Although it
57 is not possible to estimate the number of beach related injury and drowning incidents globally,
58 lifeguards rescue tens of thousands of people in distress each year and beach related fatal drownings
59 worldwide are easily in the hundreds (Gilchrest and Branche, 2016). Each surf drowning is associated
60 with significant emotional, societal and economic costs and in the case of serious near drowning or
61 surf-related injuries, may also involve lifetime medical costs (Sherker et al., 2008).

62 It is now well established that the main cause of fatal drowning and lifeguard rescue on surf beaches
63 globally are rip currents (e.g. Gensini and Ashley, 2009; Brighton et al., 2013; Arozarena et al., 2015;
64 Brander and Scott, 2016). These strong, narrow, often channelised seaward flows of water (Figure 1a)
65 originate within the surf zone and sometimes extend well beyond the seaward extent of breaking
66 waves (Castelle et al., 2016a). Rip currents flow at speeds often exceeding 0.5 m/s (MacMahan et al.,
67 2006; Dalrymple et al., 2011; Castelle et al., 2016a) easily capable of carrying unsuspecting bathers of
68 all swimming abilities (Drozdowski et al., 2012; 2015) into deeper water where, in the worst case
69 scenario, a combination of exhaustion and panic can ultimately result in a drowning death (Brander et
70 al., 2011). There has been a recent increase in interest in the rip current hazard (see Castelle et al.,
71 2016a for a review), in particular numerous studies have taken a socio-physical approach to profile
72 beachgoer behaviour (Ballantyne et al., 2005; Sherker et al., 2010; Williamson et al., 2012; Woodward
73 et al., 2013; Houser et al., 2016), their understanding and recognition of rip currents (Hatfield et al.,
74 2012; Caldwell et al., 2013; Brannstrom et al., 2014) and how people may escape rip currents when
75 caught in one (McCarroll et al. 2014, 2015; Castelle et al. 2016b; Van Leeuwen et al., 2016). This
76 approach has yielded valuable information assisting development of future educational interventions
77 related to the rip current hazard (Bradstreet et al., 2014; Houser et al, 2017).

78 **Fig1 comes here**

79 *Figure 1: Primary hazards to recreational beach users, with all photographs taken in SW France: (a) rip*
80 *currents, strong, narrow seaward flows through the surf zone capable of carrying bathers offshore*
81 *often leading to drowning (Ph. Y. Lavigne); (b) dangerous shore-break waves, occurring mostly at high*

82 *tide, with the potential to cause severe spinal injuries (Ph. J. Lestage); (3) body boarding, body surfing*
83 *and particularly surfing are popular activities potentially causing impact injuries e.g. wounds, joint*
84 *dislocation, head and cervical spine injuries (Ph. @Lacanausurfinfo.com).*

85 However, despite this understandable focus on rip currents there are other risks to beachgoers. For
86 instance, on steep beaches the rapid transition from deep to shallow water results in
87 plunging/dumping wave conditions at the shore break that are associated with concentrated and
88 intense wave impact. In these conditions (Figure 1b), being knocked over and tumbled in the shallow
89 breaking waves can cause severe spine injuries (Robles, 2006; Puleo et al., 2016). Injuries resulting
90 from surfing and body boarding (Figure 1c) are also recognized to occur more frequently in shore-break
91 conditions (e.g. Beratan and Osborne 1987; Chang et al., 2006; Barucq et al. 2009; Hay et al., 2009).
92 Even away from the shore break, surfing is far from a safe pastime with a wide spectrum of spinal
93 pathologies sustained whilst surfing (Dimmick et al., 2013; Nathanson, 2013) as well as lacerations/cuts
94 (Moran and Webber, 2013).

95 In comparison to the rip current hazard, there has been much less research on surf zone impact injury
96 and similar surf zone related risks and exposure (Pikora et al., 2012; Puleo et al., 2016; Doelp et al., in
97 press) and most of these have been restricted to the Delaware coast in the United States. There is
98 clearly a need for studies throughout a variety of other regions and countries to examine and gain
99 insight into the range of coastal hazards causing surf zone injuries (SZIs) as well as victim demographics.
100 This knowledge can ultimately be used to assist in the development and dissemination of more
101 effective local or generic prevention interventions.

102 The south-west coast of France hosts hundreds of kilometres of attractive sandy surf beaches. This
103 region is also renowned for its pleasant climate through the year, especially the warmer summer
104 months. Each summer approximately 10-15 million people visit the Aquitaine coast in SW France
105 (Brumaud, 2016), many of whom enter the water thus exposing themselves to surf zone hazards. Each
106 summer, on the order of a thousand to a few thousands of recreational water users are injured in the
107 surf zone, with injuries ranging from mild contusion to fatal drowning, but more commonly spinal
108 injuries of varying severity, wounds and luxation (Lapaty, 2004). However, like many other coastal
109 regions globally, little is known about the epidemiology of summer SZIs along this coast.

110 The aim of this study is to provide a preliminary description and insight into SZIs along an
111 approximately 230 km section of surf beaches in SW France. The study location and injury data
112 collection are described in Sections 2 and 3, respectively. Results are presented in Section 4 and are
113 further discussed in Section 5 with respect to global implications of the findings.

114 **2. Study location**

115 **2.1. General settings**

116 The study area located in SW France extends from the Adour estuary in the south to the Gironde
117 estuary in the north (Figure 2). This 230-km stretch of coastline is interrupted by the large-scale
118 Arcachon inlet separating the Landes and Gironde coasts in the south and north, respectively (Castelle
119 et al., 2018; Figure 2). The landscape essentially consists of relatively straight sandy beaches backed
120 by high and wide coastal dunes. The coast is exposed to high-energy ocean waves generated in the
121 North Atlantic Ocean coming from the W-NW direction, with a summer-mean significant wave height
122 of 1.1 m and occasional summer events exceeding 3 m (Castelle et al., 2017). The coast is meso-
123 macrotidal with a mean tidal range of approximately 3 m.

124 It is estimated that approximately 4-5 million tourists, primarily from France and other European
125 nations, come to the Gironde and Landes coasts each year to enjoy the beach (Brumaud, 2016). The
126 coast hosts some of the finest surfing beaches in Europe attracting many surfers of all abilities. The
127 coast is characterized by only a small number of coastal resorts providing direct access to the beach.
128 Apart from these resorts, beaches are mostly accessed through coastal dune tracks from inland
129 carparks. Some of these access points lead to beaches patrolled by lifeguards with a designated and
130 supervised bathing zone, but many access points are situated on unpatrolled sections of beaches,
131 kilometres away from any lifeguard presence, a scenario also described by McKay et al. (2014) in New
132 South Wales, Australia.

133 **Fig2 comes here**

134 *Figure 2: (a) France with location of the 10 largest cities and box showing study location; (b) study*
135 *location between the 2 large black circles with the 230 km length of coast being dominated by high-*
136 *wave energy sandy beaches with the Arcachon lagoon tidal inlet delimiting the Landes and Gironde*
137 *coasts. Grey squares indicate coastal municipalities where incident/injury report forms were gathered.*
138 *(c) Aerial photograph showing the typical beach-dune landscape and wave conditions in SW France*
139 *with prominent rip current channels apparent (Ph. V. Marieu).*

140 **2.2. Primary surf zone hazards**

141 The beaches of SW France are characterised by strong rip currents (Bruneau et al., 2011) with mean
142 flow speeds reaching 1 m/s even in relatively low wave energy conditions (< 1 m wave height;Castelle
143 et al., 2016b). Channelised rip currents (Castelle et al., 2016a) are common (Figure 1a) and the meso-
144 tide range (~3 m) modulates breaking wave patterns and rip current flow throughout the tide cycle
145 (Bruneau et al., 2009). On average, rip current channels are spaced 400 m alongshore and rip current
146 activity is maximized between low and mid-tide. Other rip types (Castelle et al., 2016a) can form during
147 other stages of the tide cycle, but are much less common than channelised rip currents. At, or near,

148 high tide, waves can break close to the shoreline on the steepest beach sections creating hazardous
149 shore-break conditions (Figure 1b). During busy summer months, large numbers of surfers of all ability,
150 including surf schools, congregate in many areas away from the bathing zones. In crowded conditions,
151 surfers are exposed to additional hazards as the risk of collisions is increased (Figure 1c).

152 **3. Injury data collection**

153 The beaches of the 230 km Aquitaine open coast are patrolled by lifeguards from May to September
154 each year, with most of the (less popular) beaches patrolled only in July and August. Unlike other
155 countries, many of the lifeguards are from the general reserve of the French National Police, namely
156 the *Compagnies Républicaines de Sécurité* (CRS), who are in charge of general security missions
157 including crowd and riot control. CRS are typically trained in anti-insurrection and anti-riot techniques,
158 but some are also cross trained and serve as lifeguards on beaches in summer. For each patrolled area,
159 CRS work together with civil lifeguards under the responsibility of a CRS chief lifeguard. Each coastal
160 municipality along the coast (grey squares in Figure 2b) is responsible for the security of their stretch
161 of coast that can cover up to approximately 20 kilometres (Lège, Figure 2b). The stretch of coast under
162 the responsibility of a coastal municipality can include one or several supervised bathing areas, each
163 delimited by 2 blue flags, typically extending no more than 100 m alongshore. The beach is also
164 patrolled both to the north and to the south of the bathing area, although bathing is forbidden in these
165 areas. Some coastal municipalities, which cover a long stretch of coast, also have completely
166 unpatrolled areas. The bathing zone is typically located on a shore-connected shoal away from rip
167 currents that flow through deeper channels. Beaches are patrolled from 11AM to 7PM although
168 lifeguards often train along the beach before and after the patrolled hours.

169 Lifeguards are responsible for performing surf rescues and enforcement of beach ordinance. They also
170 respond to medical emergencies and provide medical first aid before medical services arrive at the
171 beach. During patrol hours, a flag is hoisted on a 10+ m mast with the colour indicating the level of
172 risk: (1) green flag means that bathing is watched with no particular danger; (2) yellow-orange flag
173 means that bathing is dangerous, but watched; and (3) red flag means that bathing is forbidden. Red
174 flags are usually hoisted due to high waves and dangerous surf, but also due to pollution or lightning.
175 Overall, the yellow orange flag is hoisted more than 85% of the time along Gironde and Landes coasts
176 (Lapaty, 2004).

177 Whenever a medical incident occurs on the beach, a lifeguard responds to the scene to provide patient
178 care and to potentially assist paramedics. The CRS chief lifeguard is responsible for ascertaining
179 information about the incident including patient information and surf conditions at the time of the
180 incident. Since the summer of 1999, a report is filed for every incident that occurs on the beach during

181 the lifeguard season and all incident reports are stored at lifeguard headquarters (Lapaty, 2004). At
182 the end of each summer, copies of the accident/injury incident report forms (Figure 3) are sent to the
183 CRS SW France headquarters and to the Emergency Medical Service SAMU-SMUR of the Hospital
184 Centre Côte Basque. In contrast with SZI report forms designed in other countries (e.g. Muller, 2018),
185 rip currents are not pre-defined as a check box. Instead, rip-current related incidents were deduced
186 from the indication of drowning and the comments provided in the “Accident description” box
187 indicating that the beachgoer was caught in a rip current, as for each drowning incident the causes and
188 circumstances were given in detail.

189 To save time in the data collection process, not all variables listed on report forms and filled in by the
190 lifeguards (Figure 3) were entered into our database. Variables examined were as follows: date; beach
191 location (municipality); start time of the incident; flag colour; accident inside or outside of the bathing
192 zone; age; gender; country and home postal code of the victim; activity (wading/swimming, surfing,
193 bodyboarding, other); cause of injury (rip current, shore break, collision against someone else, collision
194 against their board, collision against someone else’s board, falling, other); injury type (drowning,
195 wound/contusion, spine/cervical, fracture/luxation, other), and additional comments if relevant to the
196 injury. In case of a drowning incident, the drowning stage was also provided according to a 4-stage
197 classification widely used in France (Menezes and Coasta, 1972; Dupoux et al., 1981): (1) exhaustion,
198 but no sign of aspiration of water; (2) moderate respiratory impairment, anxiety; (3) altered
199 consciousness, severe respiratory impairment or acute pulmonary oedema, tachycardia or
200 hypotension; (4) coma, respiratory or cardiac arrest. Only incidents that occurred in the surf zone were
201 gathered in the dataset.

202 Unfortunately, large data gaps exist essentially because the forms have not been properly archived
203 and stored, sometimes including entire lifeguard seasons, making it impossible to analyse temporal
204 trends of SZIs. Although we did our best to retrieve as much data as possible both at the CRS SW France
205 headquarters and at the academic health centre of Bayonne, data from only 8 lifeguard seasons were
206 collected (out of 17), 3 of which were incomplete. In this study, data from the 3 most recent full
207 summer seasons were analysed. The 2 other full summer seasons (2000 and 2001) were disregarded
208 to focus on the more recent SZIs statistics. This dataset consists of 2523 incident report forms gathered
209 over a total of 186 individual calendar days during the summers of 2007, 2009 and 2015. Of these,
210 99.6% describe incidents that occurred in July or August, with only 12 calendar days in July/August
211 having no form reported along the entire coast. Dataset limitations will be discussed in Section 5.

212

Fig3 comes here

213 *Figure 3: An example of a CRS lifeguard incident/injury report form used in SW France. In this example,*
214 *information that is used (blue) and not used (light grey) for the data collection and further analysis is*
215 *indicated.*

216 **4. Results**

217 Reports were obtained from all 23 municipalities shown in Figure 2b, with the municipality of the busy
218 coastal resort of Lacanau providing the largest amount of data (14.7%; $n = 371$). Figure 4 provides an
219 overview of SZI types including primary cause and beachgoer activity at time of incident. Drowning
220 (from stage 1 to 4) only covers 11.1% ($n = 281$) of the injuries (Figure 4a). The most common injury
221 type is fracture/luxation (33.6%; $n = 847$) followed by wound/contusion (20.3%; $n = 511$) and
222 spine/cervical injuries (18.6%; $n = 470$). Various other injuries were also reported (16.4%; $n = 413$) such
223 as minor pains that did not require any assistance. Shore-break waves are the most important cause
224 of SZIs (44.6%; $n = 1125$, Figure 4b), of which can be added impacts with other wading people (6.4%; n
225 $= 162$) that primarily occur in shore-break waves in crowded bathing zones. Figure 4b shows that
226 another large proportion of injuries are related to surfing (31%; $n = 783$) and bodyboarding (5.3%; $n =$
227 134) activities as evidenced by the large proportion of injuries caused by collision against their board
228 (19%; $n = 479$), someone else's board (2.3%; $n = 68$) and falling (10.1%; $n = 254$), although the latter
229 involves a majority of wading beachgoers. Wading/swimming is the most common activity recorded in
230 the incident/injury report forms (61.2%; $n = 1543$, Figure 4c).

231 **Fig4 comes here**

232 *Figure 4: Surf zone incidents related to: (a) injury type; (b) primary cause; and (c) activity.*

233 Figure 5 shows the distribution of SZIs according to age and gender for the entire dataset (Figure 5a)
234 and for specific activity, primary cause and injury type (other panels in Figure 5). Figure 5a shows that,
235 overall, males were most frequently injured, comprising 69.6% ($n = 1617$) of the entire sample. The
236 distribution of age group within gender was non-normal, with on average injured females being
237 younger than males. The median and mean age was 24 (19) years and 28.3 (26.0) years for males
238 (females), respectively. Two age groups stand out in particular: i) 10-25 years (39.5% females, 60.5%
239 males) representing 54.5% ($n = 1376$) of the dataset; and ii) 35-50 years (30.7% females, 69.3% males)
240 representing 22.6% ($n = 570$; Figure 5a). Similar age/gender distributions are observed for
241 swimming/wading activity (Figure 5b) and shore-break related injuries (Figure 5c). In contrast, the
242 population injured while surfing is younger with 62.6% ($n = 490$) within the age group 10-25. Of note,
243 the spine/cervical injury population is even younger with 58.5% ($n = 313$, Figure 5e) within the age
244 group 10-20. Within the age group 10-25 of the drowning population (all stages included), which is
245 associated with 52% of the drowning incidents, the majority were females (58.2%; $n = 85$) in contrast

246 with all the other gender distributions. Table 1 provides more insight into the drowning population
 247 and shows that there is a large majority (74.1%; $n = 33$) of males involved in severe drowning incidents
 248 (stages 3 and 4), while milder drowning incidents (stages 1 and 2) are approximately equally distributed
 249 between males and females. Overall 79% ($n = 222$) of the drowning incidents are caused by rip
 250 currents, a proportion that ranges from 50%-82% depending on the drowning stage (Table 1).

251 **Fig5 comes here**

252 *Figure 5: Age and gender distribution of SZIs for: (a) all incidents; and specific activity, primary cause*
 253 *and injury type: (b) wading/swimming; (c) shore break; (d) surfing; (e) spinal injuries; and (f) fatal and*
 254 *non-fatal drowning.*

255 *Table 1. Drowning incidents as related to gender, location (inside or outside of the bathing zone) and*
 256 *rip currents. The gender of 1 out of the 14 stage 3 drowning victims was not filled in the form.*

| Drowning stage | Total | Male | Female | Inside bathing zone | Outside bathing zone | Rip current |
|-----------------------|--------------|------------------|------------------|----------------------------|-----------------------------|--------------------|
| 1 | 26 | 10 (38%) | 16 (62%) | 16 (62%) | 10 (38%) | 19 (73%) |
| 2 | 223 | 114 (51%) | 109 (49%) | 91 (41%) | 131 (59%) | 183 (82%) |
| 3 | 14 | 8 (62%) | 5 (38%) | 6 (43%) | 8 (57%) | 7 (50%) |
| 4 | 18 | 15 (83%) | 3 (17%) | 0 (0%) | 17 (100%) | 13 (76.5%) |
| Total | 281 | 147 (52%) | 133 (48%) | 113 (40%) | 166 (60%) | 222 (79%) |

257 Figure 6 shows the hourly variation of SZIs. 93.6% ($n = 2362$) of injuries occurred during patrolled hours,
 258 peaking at 18.9% ($n = 533$) between 4-5PM with the majority of injuries (51.8%; $n = 1357$) occurring
 259 between 3-6PM. While there is no significant hourly variation in the injured gender distribution, 56.4%
 260 ($n = 368$) of injuries in the morning and early afternoon (before 2PM) are related to surfing activities.
 261 This is largely because: i) beaches are not yet crowded with beachgoers enjoying swimming and
 262 wading; ii) surf schools typically provide surf training courses in the morning and early afternoon; iii)
 263 offshore wind conditions, which greatly improve surf-break quality, generally occur early in the day
 264 before the onshore marine sea breeze picks up.

265 **Fig6 comes here**

266 *Figure 6: SZI occurrence as a function of time and as a function of (a) gender and (b) activity.*

267 Overall, 48% ($n = 1210$) of SZIs occurred inside the bathing zone, albeit with large variabilities of injury
 268 type (Figure 7). A large proportion (81.8%; $n = 418$) of wound/contusion injuries occurred outside of
 269 the bathing zone. This is due to these injuries being sustained primarily when surfing (73.4%; $n = 375$)

270 and because 100% of the injuries related to surfing occurred outside of the bathing zone as surfing is
271 forbidden in these zones. Of interest, Figure 7 also shows that spine/cervical and fracture/luxation
272 injuries primarily occur inside the bathing zone. This is because spine/cervical (73.8%; $n = 347$) and
273 fracture/luxation (66.4%; $n = 562$) are primarily sustained in the shore break, and because 74.1% ($n =$
274 834) of shore-break-related injuries occur inside the bathing zone. These findings highlight that shore
275 breaks are clearly a major hazard in the bathing zone when beachgoers enter the water. Finally, a
276 substantial amount (40%; $n = 113$) of drowning incidents occur inside the bathing zone. However,
277 94.7% ($n = 107$) of these drowning incidents were of mild severity (stages 1 and 2, see Table 1), and no
278 fatal or stage 4 drowning occurred in the bathing zone in this dataset. This is presumably because water
279 is shallow and water users are close to shore favouring self-rescue and enabling supervising lifeguards
280 to react quickly to incidents.

281

Fig7 comes here

282 *Figure 7: Percentage of SZI types inside (blue) and outside (red) of the bathing zone.*

283 The number of SZIs per day was highly variable in the dataset, with some days having no incident
284 reports and others with a large number of SZIs. August 18 2007 received the highest number of
285 incidents (60) with a proportion of primary causes and injury types roughly in line with the overall
286 dataset presented above. More interesting were the second and third days with the highest number
287 of SZIs. August 4 2009 and August 20 2009 were characterized by 59 and 52 SZIs, respectively. Both
288 days were dominated by injuries caused by the shore break corresponding to 81.4% and 76.9% of the
289 incidents, respectively. This demonstrates that the shore break can be highly hazardous to swimmers
290 and that widespread incidents can occur even inside the bathing zone during particular days. Other
291 days were also particularly prone to drowning due to rip currents. August 5 2007 was the day with the
292 highest number of drowning incidents (17; 14 stage 2, 1 stage 3 and 2 fatal stage 4) corresponding to
293 45.9% of incident forms filled in that day.

294 Beach location and home postal code for each victim allowed a systematic quantification of the
295 distance between the French victim and the beach. Overall, 85.3% ($n = 1943$) of the victims were
296 French when postal address was provided (90.3%, $n = 2278$). Although it is not possible to comment
297 on the beachgoing frequency of the victims, those living within 40 km from the beach where the injury
298 occurred were subjectively described as 'locals' and those beyond that distance described as 'non-
299 locals' as they typically have more than a half-hour drive from their home to the beach. Approximately
300 89% ($n = 1729$) of French victims were non-locals, while 90.6% ($n = 2064$) of all victims were non-locals.
301 Figure 8 shows that 13.3% ($n = 335$) of victims were European (non-French) with the most common
302 countries of origin being The Netherlands (44.2% of non-French European; $n = 148$), followed by
303 Germany (26.3% of non-French European; $n = 88$) and Belgium (12.5% of non-French European; $n =$

304 49), which are all coastal countries, albeit with different wave climate and surf zone current conditions
305 to SW France. Figure 9 provides more insight into the geographical distribution of the French victims.
306 Peaks clearly identify the victims from the closest and largest French cities shown in Figure 2a with, for
307 instance, victims from the nearby large cities of Bordeaux and Toulouse standing out. These patterns
308 are consistent for both wading/swimming and surfing activities (Figure 9).

309 **Fig8 comes here**

310 *Figure 8: Geographic distribution of SZIs in SW France (from patient home postal code).*

311

312 **Fig9 comes here**

313 *Figure 9: Distribution of the distance between the beach and patient home (from postal code) as a*
314 *function of activity.*

315 **5. Discussion and conclusions**

316 The patterns of SZIs along the high wave energy sandy beaches of SW France show some clear
317 similarities with findings in other countries. The predominant age group involved in the incidents was
318 between 10-25 years, the majority of SZIs (69.6%) involved males, and most victims were non-locals,
319 which is consistent with trends found elsewhere (UK: RNLI, 2014; USA: USLA, 2015; Australia: SLSA,
320 2017). The three primary causes of SZIs found in this study, namely rip currents, shore break and
321 surfing activity, which were mostly treated separately in other studies (e.g. Barucq et al., 2009;
322 Brighton et al., 2013), are also clearly identified as the three primary hazards to recreational
323 beachgoers in SW France. The major difference here is that these three primary hazards were
324 addressed together in relation to SZI type, allowing a better assessment of the relative proportions
325 and severity, which is critical to making more informed decisions about funding and targeting public
326 safety programs. Wading was also identified to be the dominant activity associated with SZI (61.2%),
327 also consistent with other studies (e.g. 50.1% on the Delaware beaches, Doelp et al., in press).

328 Some findings in this study are inconsistent with observations along other coasts. An example is the
329 large proportion of females (48%) involved in drowning incidents on beaches in SW France. This is in
330 contrast to all existing drowning epidemiology studies (Brighton et al., 2013; USLA, 2015; SLSA, 2017),
331 which highlight the large predominance of young males in drowning incidents. Indeed a recent beach
332 safety educational campaign by Surf Life Saving Australia has focussed on targeting young males
333 (<https://sls.com.au/young-men-risk-getting-caught-dying-rip-currents/>). Although beyond the scope
334 of this study, the physical, social and cultural reasons why young females are highly exposed to
335 drowning incidents in SW France should be explored further. Both males and females within the age
336 group between 35-50 years old were also found to be the second most common age group receiving

337 SZIs, similarly to the anomalous and unexplained peak in the 35–55 age of SZIs reported along the
338 Delaware coast (Puleo et al., 2016). Reasons to explain this are also unclear, although it is possible that
339 somewhat older children are more likely to be less supervised by 35-55 aged parents and that declining
340 physical fitness place middle aged adults at high risk. This can also be the signature of the vulnerable
341 "weekend warriors" (Roberts et al., 2014), a category of people, most likely middle-aged, who are
342 active, but not on a regular basis and tend to engage in demanding recreational sporting activities at
343 similar intensities to when they were aged in their 20s. This can also be due to the beach user
344 demographic, which will be discussed later. Finally, contrary to other studies performed along
345 coastlines with a large range of wave exposures and different beach types (e.g. Arozarena et al., 2015),
346 there was little spatial variation in in SZI data along the quasi-straight sandy coast of SW France.

347 The fact that shore-break waves are the most important cause of SZIs (44.6%) is also somewhat
348 surprising as this is not the case in other countries where rip currents are by far the primary cause (81
349 % USA (USLA, 2015); 57.4 % Australia (Brighton et al., 2013); 45 % UK (RNLI, 2014)). Contrary to SW
350 France, shore-break waves are typically associated with a low proportion of surf zone hazards in most
351 of existing studies (8.5 % Australia (Brighton et al. 2013); UK 16 % (RNLI 2014)). Notable exceptions can
352 occur, such as along the steep beaches of the Delaware coast where shore-break waves are identified
353 as the primary surf zone hazard (Puleo et al., 2016; Doelp et al., in press), although the proportion with
354 respect to the other surf zone hazards was not quantified. The beaches of SW France are, however,
355 not particularly steep except near high tide, which limits the temporal duration of, and exposure to,
356 hazardous shore-break conditions (Masselink and Short, 1993). Clearly the link between tide/beach
357 slope and shorebreak injuries should be investigated further, but is beyond the scope of the present
358 study. Finally, although the SW coast of France is known to attract many surfers, both from France and
359 other European countries, the rate of SZIs related to surfing activity is surprisingly high (31%) compared
360 to elsewhere. For instance, only 3% of SZIs are related to surfing activity along the Delaware coast
361 (Doelp et al., in press), behind body surfing (13.3%) and body boarding (18.4%). Although this was not
362 quantified here, a large proportion of the injuries associated with surfing activity occurred during learn
363 to surf courses as often indicated by the accident description in the incident/injury report forms.

364 The results of this study are similar to those of Puleo et al. (2016) in that there were particular days
365 with high numbers of SZIs suggesting that there may be causal relationships with specific physical
366 conditions relating to waves, tidal stage, and beach morphology and weather conditions and water
367 temperatures that influence beach attendance and water entry, and therefore beachgoer exposure.
368 Puleo et al. (2016) attempted to relate injury occurrence to environmental factors (including in-situ
369 wave height, tidal stage and foreshore slope measurements) and found only weak correlations, but
370 noted that the highest injury rates were associated with moderate wave height (0.6 m). In the absence

371 of clear correlations, they suggested that SZI rates are likely related to human factors. In contrast, Scott
372 et al. (2014) used 5-year lifeguard incident records from 20 beaches in southwest England together
373 with wave and tide data and further found high correlations between environmental factors and rip-
374 related rescues. They also showed considerable environmental control on mass rescue events. Physical
375 conditions at the time of the injury such as wave height, period and direction, tidal stage, beach slope,
376 water and air temperatures, wind and insolation were not recorded in the lifeguard incident forms
377 addressed herein. However large-scale numerical weather and wave hindcast data are available along
378 this stretch of coast (e.g. Masselink et al., 2016), along with data collected at nearby weather stations,
379 which can be used instead. However, with the exception of regular topographic data collected at Truc
380 Vert beach (Castelle et al., 2017), which is located approximately 15 km south of Le Porge on the
381 Gironde coast (Figure 2b) and not representative of all the beaches along the coast, beach slope data
382 is unavailable. There are some qualitative findings which suggest that rip-current and shore-break
383 related injuries preferably occur around low and high tide, respectively, both for low- to moderate-
384 energy waves. However, the detailed analysis is beyond the scope of this paper due to the apparent
385 complexities in the relations between forcing and injury types, and this will be the subject of a future
386 study as a key contribution of this effort is to demonstrate the relative contributions of different SZI
387 types. The development of a risk predictor for a given surf zone hazard, which has been fairly successful
388 in other countries using approaches of varying complexity (e.g. Lushine, 1991; Austin et al., 2013;
389 Moulton et al., 2017) would clearly have beneficial implications for lifeguard management and
390 beachgoer safety along the coast of SW France. Similarly, further investigation is needed to provide an
391 accurate assessment of beachgoer demographics and beach usage in general, which is a critical
392 component of any risk predictor, but remains a challenge for all beach safety related research
393 (Brander, 2018).

394 Our results have other strong implications in terms of beachgoer management and safety. First, as
395 most severe drowning incidents and all fatal drownings occurred well away from the bathing zones,
396 the safety message “swim between the flags” during the patrolled season must be better
397 communicated to the public. Second shore-break conditions are clearly highly hazardous, even within
398 the patrolled bathing zone, particularly during specific days as described above. These shore-break
399 related injuries can be severe. For example, one of the two stage-4 drowning deaths in the summer of
400 2015, a healthy middle-age male, occurred in the shore break away from the bathing zone and was
401 diagnosed with a severe whiplash and subsequent drowning. However, to our knowledge, educational
402 interventions about dangerous shore-break conditions are non-existent in SW France. The lack of
403 shore-break education and awareness has been pointed out in other studies. For instance, even on
404 severely rated shore-break beaches in the US with dedicated shore-break warning signs less than 20%

405 of the beachgoers actually saw the warnings (Doelp et al., in press). In addition to posting shore-break
406 warning signs at relevant locations, a shore-break awareness campaign is clearly required in SW France
407 to limit severe injuries so that beachgoers understand that, even inside the bathing zone, wading and
408 swimming may not be safe. Third, rip currents clearly represent a major hazard to beachgoers in SW
409 France, and are by far the leading deadly surf zone hazard. Although some rip-current educational
410 interventions exist, they are not as well-developed, coordinated, prevalent or effective as they are in
411 other countries such as the US, Australia and the UK (Brander and Scott, 2016). Given that 85% of the
412 rip current drowning victims along the SW Coast were French, a strong need exists for a national rip
413 current education program building on the lessons gained from other countries (e.g. Houser et al.,
414 2017).

415 Our study has a number of limitations common to other beach safety related studies. First, accurate
416 incident reporting of beach related injuries is a global challenge (Williamson, 2006) and as stated
417 earlier in this paper, although the lifeguards were efficient in reporting, many reports were
418 subsequently lost since 1999 making it impossible to conduct a robust SZI analysis throughout the last
419 17 years. Accordingly, the years 2007, 2009 and 2015 may not be entirely representative of the
420 variability in SZIs in SW France. While improving incident reporting amongst lifeguards is a global
421 challenge, in France a first step is to properly archive and store the data. Second, our results show that
422 there is a reasonably low proportion of SZIs related to rip currents, although rips are by far the leading
423 deadly hazard in the dataset. However, it is important to note that rip-current related rescues were
424 filled in only when drowning incidents occurred. The numerous timely and efficient rip-current rescues
425 performed by lifeguards and by bystanders (Scott et al., 2014; Attard et al., 2015; Moran et al., 2017)
426 were therefore ignored. The rip current hazard is therefore largely under-represented here.

427 The fact that the spine/cervical injury population along the SW Coast of France is very young, with
428 58.5% within the age group 10-20, warrants further investigation. For instance, personal
429 communication with local lifeguards indicates that lifeguards are more cautious with young people,
430 with any suspicion of spinal injury typically being recorded as a spine injury in the forms, which would
431 not be the case with an adult. Finally, although it is a strong limitation of all the epidemiology studies
432 of SZIs, it is important to emphasize that the demographic profile of beachgoers is largely unknown.
433 For instance, the 35-55 age group peak may just be the signature of a higher proportion of middle aged
434 beach visitors. Another related issue is the exposure rate, which depends on the number of people
435 who enter the water when they are at the beach, which is variable in time and space and is virtually
436 unknown. Therefore, addressing the demographics and exposure of beachgoers is a paramount to
437 further understand the epidemiology of SZIs (Woodward et al., 2013). Finally, due to lack of suitable
438 data, we are unable to relate our findings to social factors such as beachgoer behaviour, visitation

439 patterns, and water entry intentions in relation to flags and signage, similar to recent social based surf
440 hazard research (e.g. Brannstrom et al.,2015; Barlas and Beji, 2016; Houser et al., 2016). Such a study
441 is clearly needed and would provide valuable socio-cultural insights into French and European
442 beachgoers in comparison with those in other countries.

443 Regardless of these limitations, our study provides the first overview of SZIs in SW France. Injuries
444 sustained range from mild contusion to fatal drowning and included severe spinal injuries, wounds and
445 luxation. While the most severe injuries are related to rip currents, a large number of SZIs occurred as
446 a result of shore-break waves and surfing activity primarily inside and outside of lifeguard patrolled
447 bathing zones, respectively, with patterns differing from those reported elsewhere. We found a
448 predominance of young males in the reported SZIs and severe drowning incidents, and a surprisingly
449 high number of females. This calls for the development of improved awareness campaigns in France
450 on rip currents and shore-break waves that are particularly targeted towards young males and females
451 in order to reduce the number of injuries and drownings occurring on beaches in SW France. These
452 campaigns should always emphasise the importance of bathing only between the flags and in the
453 presence of lifeguards.

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Figure 2

[Click here to download Figure Fig2.jpg](#)



Lifeguard's: Northern beach station Start: 17 h 15 End: 18 h 00 Accident on the beach Yes No
 Flag: G Y R Patrolled hour Yes No
 Pattrolled area Yes No Bathing zone Yes No

IDENTITY

NAME: XXXXXX xxxx Age: 29 M F
 Adress: 23, Second Street, 33600

ACCIDENT

Activity: Wading / swimming Surfing Bodyboarding Shorebreak Other
 ► Accident description: In the bathing zone she got pounded by a shorebreak, swallowed a little bit of water. She was able to go back to shore alone.
Saved by: Lifeguard Helicopter Boat Bystander Alone Other

MEDICAL REVIEW

Faint:: Yes No
Desease: Yes No
 ● Drowning stage 1 2 3 4
Traumatology:

| | Head | Spine | Limb | Thorax | Abdomen |
|-----------|------|-------|------|--------|---------|
| Contusion | | | | | |
| Wound | | //// | | | |
| Fracture | | | | | //// |
| Luxation | //// | | | //// | //// |

● Other
 ► Summary: The victim is shocked, with moderate respiratory impairment

VITAL SIGNS

Conscious Yes No Initial loss of consciousness
Breathing Yes No Labored
Pulse: Yes No

SEVERITY

No severity Mild severity
 Severe Very severe
 Fatal

CARE

O₂ Cervical collar Upper airway release Ventilation Recovery position Chest compression

TRANSPORT FROM THE BEACH

Fire brigade Emergency Medical Services Helicopter Private Ambulance On their own Local doctor
Towards: Hospital Clinic Doctor office No transportation Medical committee
xxxxx Location name REFUSAL

► Intervention lifeguard(s): (optional) xxxxx xxxxx

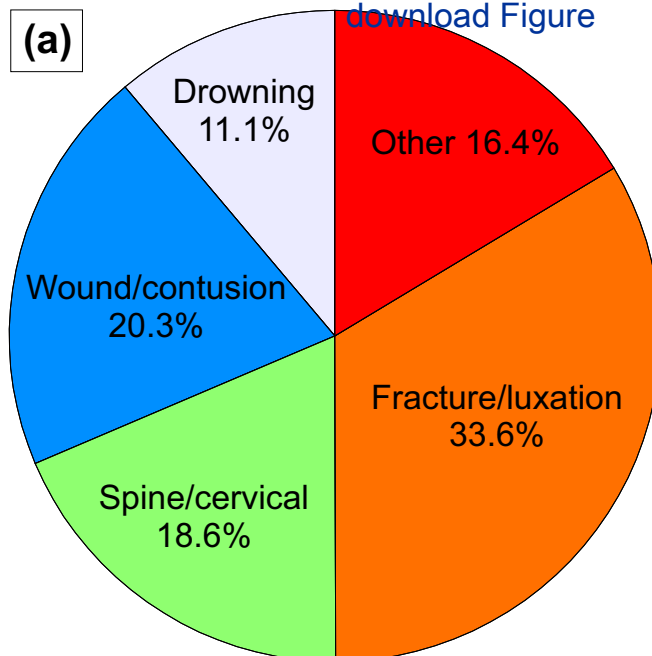
Lifeguard Chief: xxxxx

Figure 4

Injury $n = 2523$

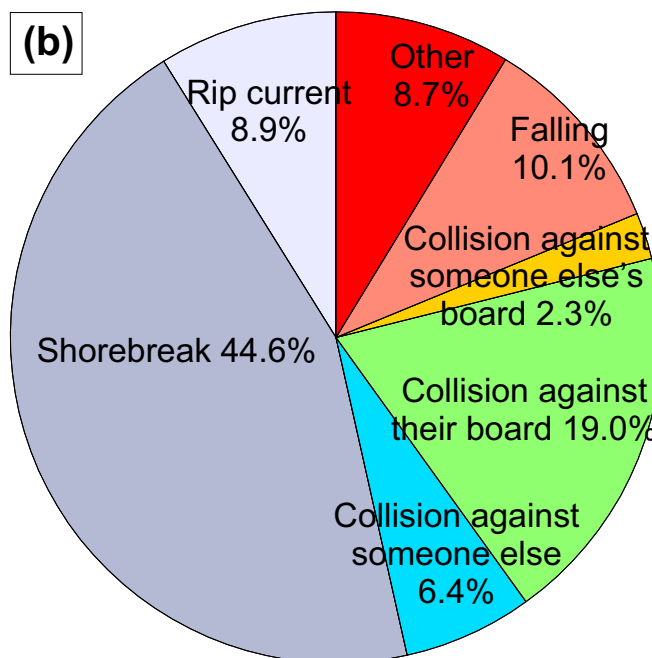
[Click here to download Figure](#)

(a)



Primary cause $n = 2523$

(b)



Activity $n = 2523$

(c)

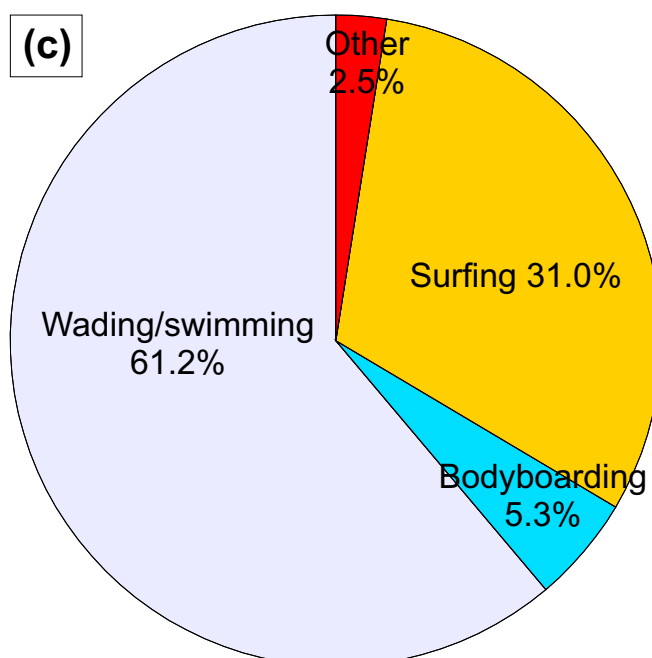
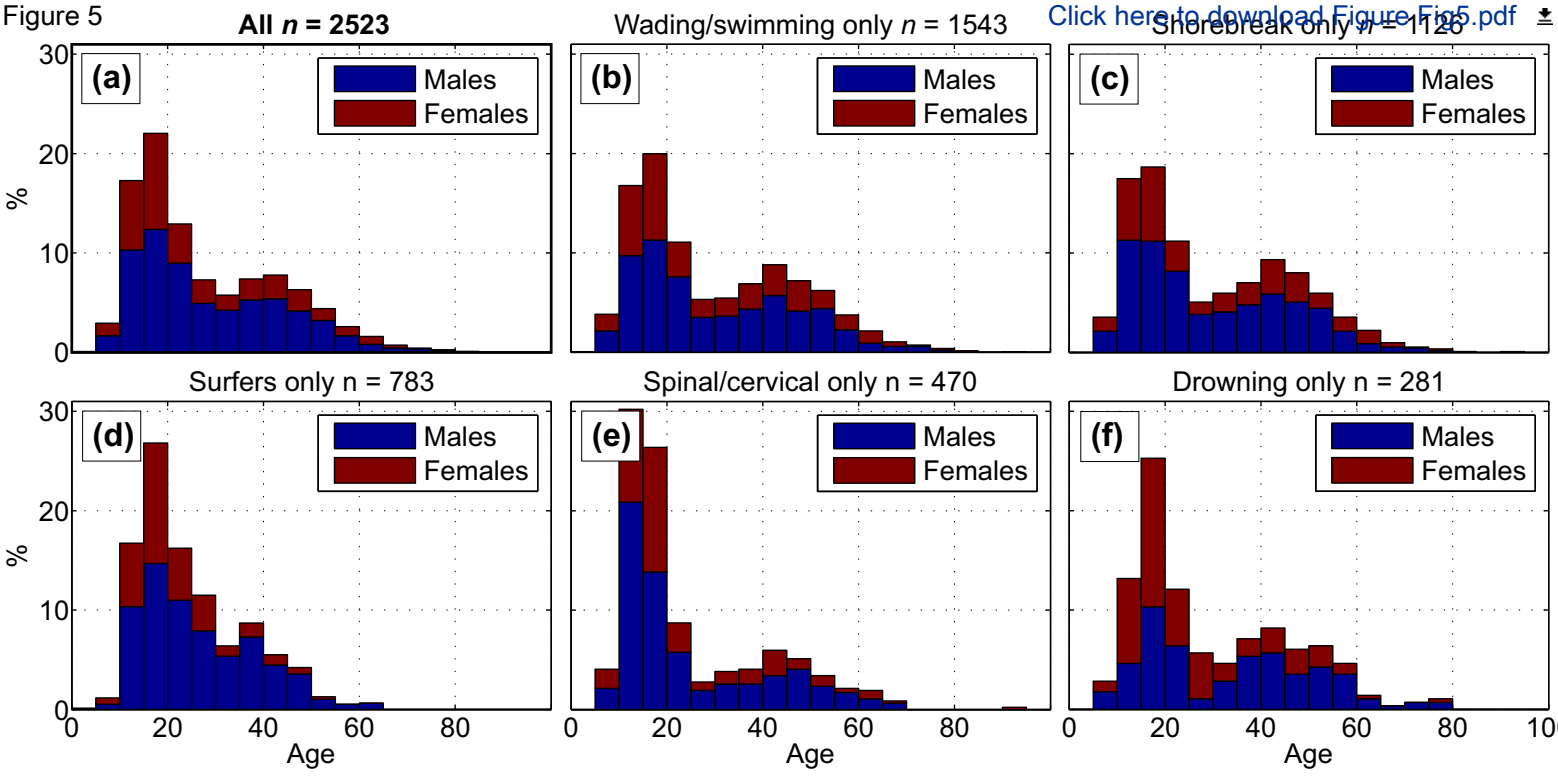
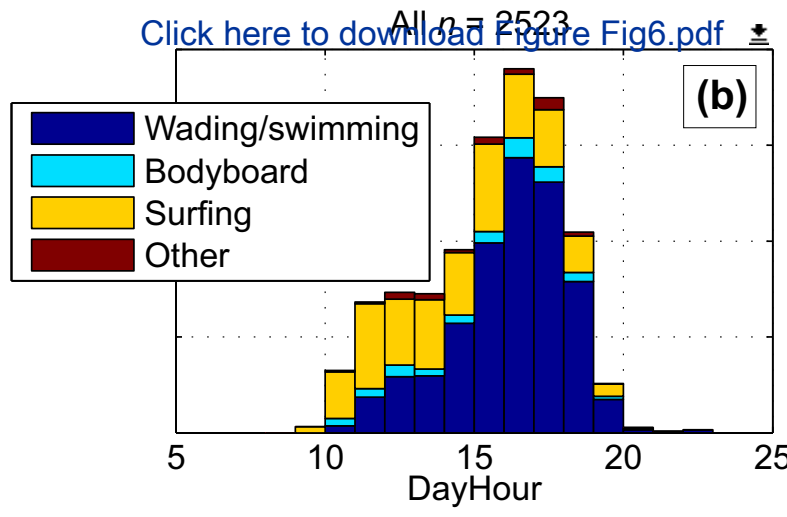
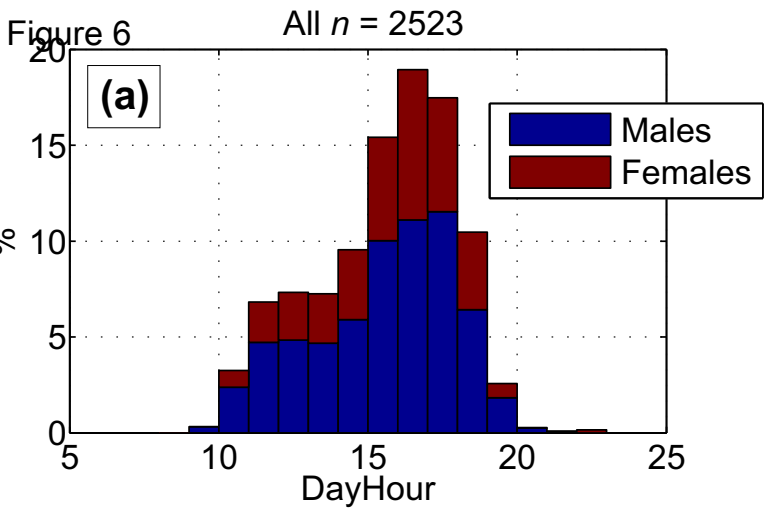


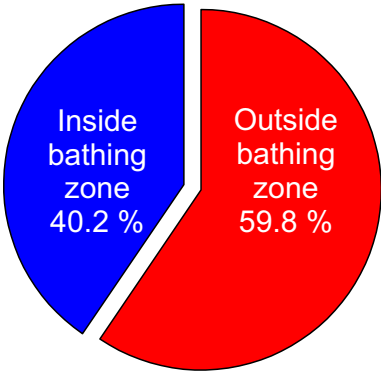
Figure 5



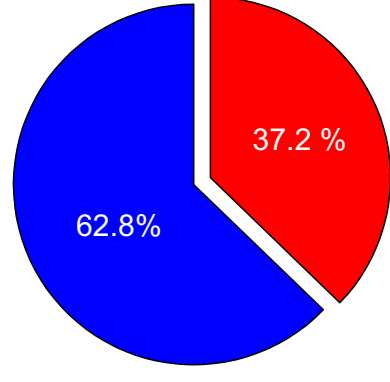
[Click here to download Figure-Fig5.pdf](#)



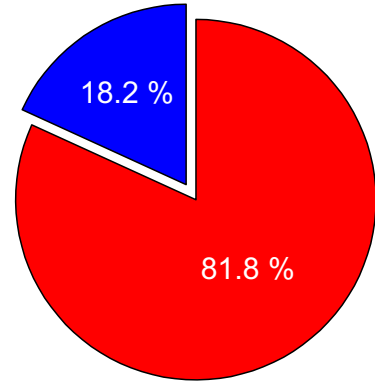
Drowning *n* = 281



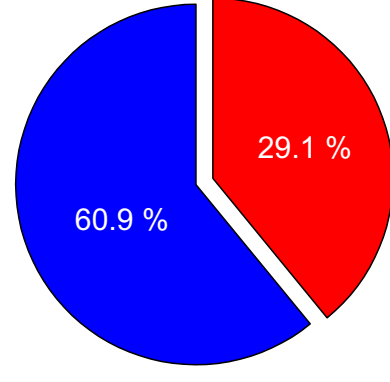
Spine/cervical *n* = 470



Wound/contusion *n* = 511



Fracture/luxation *n* = 847



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Figure 8

Origin $n = 2523$

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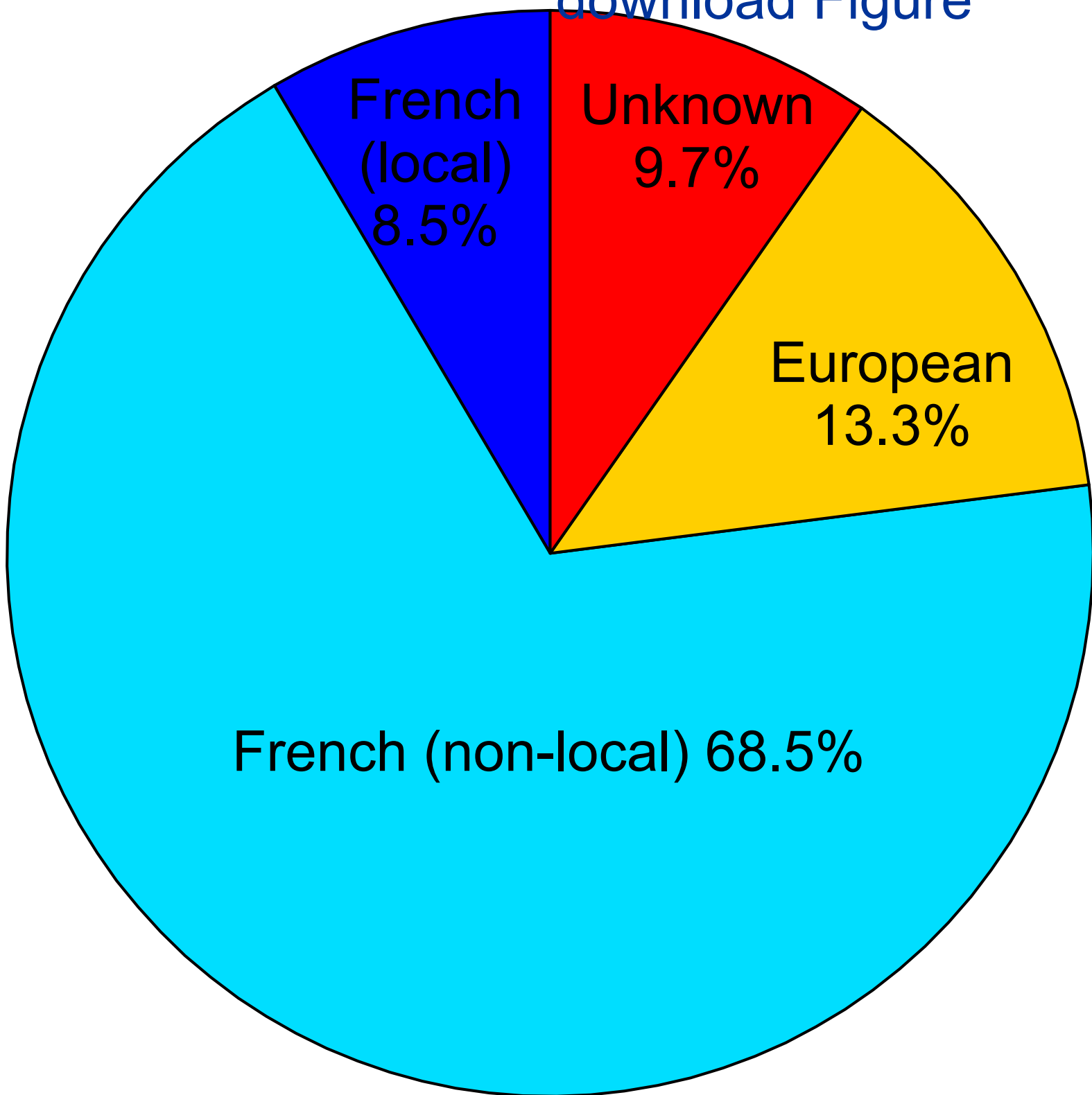


Figure 9

French only $n = 1943$ [Click here to download Figure Fig9.pdf](#)

