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Beach Rescue Statistics and their Relation to Nearshore Morphology and Hazards: A Case Study for Southwest England

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ABSTRACT

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The coasts of Devon and Cornwall in the southwest of England experience some of the most energetic wave conditions ($H_{s,10\%}$ = 2–3 m) and largest tide ranges MSR = (4.2–8.6 m) in the UK. They are also a popular tourist destination during the summer months with over 10 million visitors per year. The energetic wave/tide conditions pose a considerable physical risk to beach users and 62 beach environments in this region are therefore patrolled by Royal National Lifeboat Institution (RNLI) lifeguards. Beach rescue statistics collected by the RNLI during spring and summer (1 May to 1 October) were analysed to examine and quantify the risk posed by physical beach hazards to beach users. Rip currents were found to be the main hazard and were responsible for 71% of all recorded incidents. The most hazardous beaches were found on the exposed west coast of the study area. Beaches here can be classified as morphodynamically intermediate and are characterized by low-tide tide bar and rip systems, often topographically-constrained by intertidal geology. The rip currents are generally most active around low tide. Beaches in Devon and Cornwall exhibit morphologies that are significantly different from previously studied beaches in Australia due to the combination of high energy surf zones, large tides and variable coastal geology. This work represents a first step towards the generation of standardized beach risk assessments in the UK.

ADITIONAL INDEX WORDS: *Beach safety, Rip currents, Beach type, High energy, Macro-tidal.*

INTRODUCTION

Due to its location and geological setting, the United Kingdom (UK) possesses a very broad spectrum of beach environments around its more than 5,000 km long shoreline. UK beaches attract a large number of visitors annually for their aesthetic, sport and recreational appeal, providing pivotal support to the tourism industry in many regions. However, the beach environment is inherently hazardous and exposes people to risk. To understand and manage this risk, a comprehensive understanding of UK beach environments and their associated hazards is needed.

Beach hazards in this study represent any phenomena which place the beach user in danger and are related to beach morphology and nearshore hydrodynamics. Hydrodynamically-driven hazards manifest themselves as breaking waves, bores and set up; variable water depth; and nearshore currents, driven by waves, tide and wind. In association with beach morphology, these forces can move people unwillingly around the nearshore zone, placing them at risk. Intertidal and backshore geology constrains the characteristics of the beach and surf zone, and introduces localised hazards such as reefs, rocks and shore platforms (SHORT and HOGAN, 1994).

As one of the most diverse coastlines in the world, the UK experiences Mean Spring tide Ranges (MSR) of 1.5–15 m, and a wave climate gradient from exposed ocean swell to fully protected wind-wave environments. Wind, wave and tidal processes produce dynamic nearshore current systems that play an important part in forming the wide range of beach morphodynamic states that exist around the UK. The geological setting of these beach environments includes high hard-rock cliffs, low soft-rocks cliffs, embayed coves and open ocean beaches, river mouths, tidal inlets, estuaries, spits and barriers. Beach sediments range from fine sand to boulders, and gravel beaches are particularly well represented in the UK due to its glacial history (MAY et al., 2003). With high population density in coastal areas, human modification is a significant feature around the UK beaches and has acted to alter beach shape and hydrodynamics through the implementation of groynes, breakwaters and sea walls (FRENCH, 2001).

This study focuses on the coasts of Devon and Cornwall in the southwest of England. This region, as well as being a popular tourist destination during the summer months with over 10 million visitors a year, experiences some of the most energetic wave conditions in the UK with 10% exceedence wave heights ($H_{s,10\%}$) reaching 2.5 to 3 m on western coasts (DRAPER, 1991). This wave climate is characterised by a mixture of Atlantic swell and locally generated wind waves, and exhibits a MSR ranging from 4.2 to 8.6 m (UK HYDROGRAPHIC OFFICE, 2003). In conjunction with the Royal National Lifeboat Institution (RNLI), who provide beach lifeguarding services to 62 beaches in the region, this study analyses the beach rescue statistics in association with physical beach characteristics and hydrodynamic conditions, examining the hazards posed to the beach user through interaction with the beach

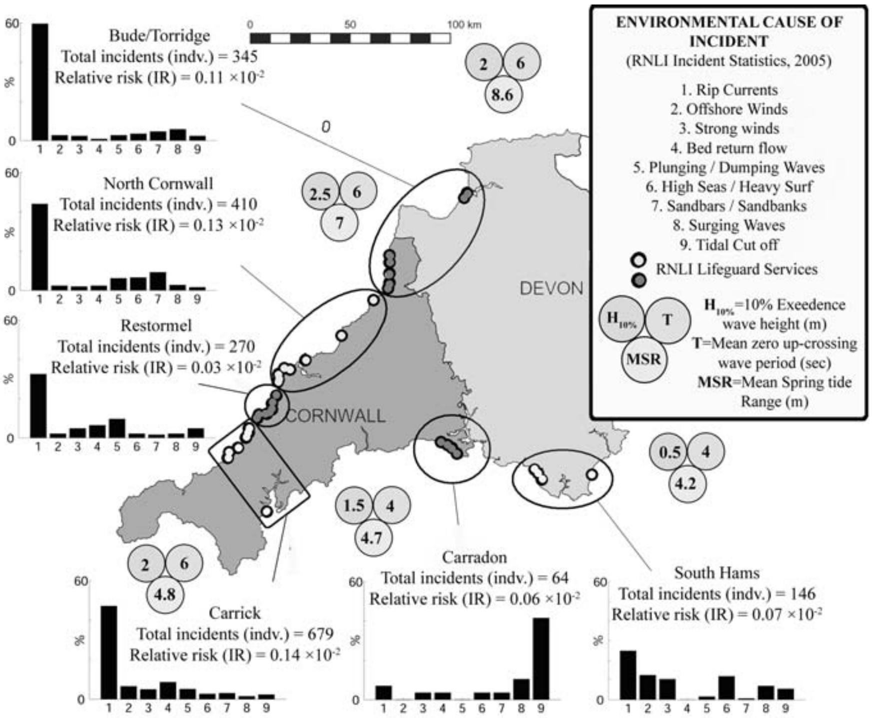

Figure 1. Plots illustrating percentage distribution of the environmental cause of incident for all cases of active assistance at RNLI-patrolled beaches in Devon and Cornwall during 2005. Total number of individuals (indv.) assisted and relative risk posed by physical beach hazards (IR=incidents.hr^{-1}/people in-sea.hr^{-1}) are displayed for each region. Circles represent 10% exceedence significant wave height (DRAPER, 1991), mean zero up-crossing wave period (DRAPER, 1991) and mean spring tidal range (UKHO, 2003). The histograms show the environmental cause of incident.

and nearshore zone under typical spring/summer season conditions (1st May to 1st October). An improved understanding of beach hazards in Devon and Cornwall represents an initial step towards the generation of a standardised beach risk assessment for the UK.

Lifeguard services began in the UK in 1955 when the Surf Life Saving Association of Great Britain was formed (SLSA) as volunteer clubs began to patrol beaches in Bude and St Agnes in Cornwall and Brighton on the south coast of England. At present, the RNLI represent the contemporary face of beach lifeguarding, providing well-equipped and highly-trained services to 62 beaches in the southwest of England. A lifeguard service is a response to the risks posed within the beach environment and it aims to protect and educate the beach user. To best perform this task a comprehensive knowledge of site-specific physical beach hazards, hence beach morphodynamics, is needed.

Much of the pioneering work on modelling beach morphodynamic states and their associated hazards was conducted in Australia. WRIGHT and SHORT (1984) developed a beach classification model for micro-tidal, wave-dominated coasts using the dimensionless fall velocity ($\Omega = H_b/w_sT$, where H_b is breaker height, w_s is sediment fall velocity and T is wave period) to differentiate between reflective ($\Omega < 1$), intermediate ($\Omega = 1–6$) and dissipative ($\Omega > 6$) regimes. MASSELINK and SHORT (1993) extended this work to meso/macro-tidal environments by defining an additional dimensionless parameter, the relative tidal range ($RTR = MSR/H_b$), to describe the relative importance of shoaling, surf zone and swash processes across the intertidal profile. Incorporating both morphological and hydrodynamic factors, a sequence of characteristic beach morphologies can be identified on the basis of Ω and RTR, leading to the identification of distinct morphodynamic states. Recent Australian studies have associated physical hazards with beach state and temporal variation in environmental conditions, and have led to the development of the Australian Beach Safety and Management Program (ABSAMP), aimed at improving safety services for Australian beaches (SHORT, 2001).

METHODOLOGY

This study uses RNLI incident statistics and logs of observed daily conditions collected for 62 locations within the southwest of England for the 2005 lifeguarding season (1st May to 1st October) to investigate the specific hazards present within this coastal environment. Data of physical beach characteristics were collected through a campaign of 3D beach surveys using a quad mounted Trimble RTK GPS system conducted during several spring tide cycles from August to September, 2006. This was combined with sediment sampling, low-tide photographs and video from an Argus station (Perranporth only). Hydrodynamic conditions were obtained both through visual observations of wave breaker heights recorded hourly by the RNLI, statistical wave conditions from DRAPER (1991) and tidal information from the UK HYDROGRAPHIC OFFICE (2003). Estimation of beach user numbers was obtained from the RNLI daily logs where the number of beach users was estimated each hour between 10:00 and 17:00 hrs.

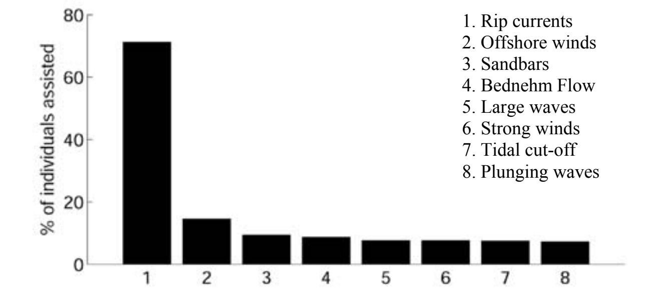

Figure 2. Plot illustrates percentage frequency distribution of environmental cause contributing to each individual assisted during the 2005 season (some assists involve more than one environmental cause)

REVIEW OF RESULTS

Incident statistics

A comprehensive database has been compiled, containing information on all RNLI incidents (a logged event of active assistance which can involve multiple individuals), daily conditions and beach population during the 2005 season from late April to early October (dates within which RNLI serviced beaches are patrolled). Incidents recorded range from a situation requiring assistance to a life threatening rescue. Detailed information is logged for each incident including the cause of incident and specific environmental factors. Figure 1 summarises the environmental cause of incident statistics for all recorded incidents during the 2005 season within each regional division.

This dataset clearly shows that during 2005 both the environmental cause of incident and the number of incidents vary significantly around the coasts of Devon and Cornwall. A dominance of rip current related incidents (47% of total incidents for 2005) is seen in most regions. Rip currents account for 49% of incidents in west coast regions where $H_{s,10\%}$ is 2.5–3 m and MSR ≈ 7m, as opposed to the south coast regions where, $H_{s,10\%}$ = 0.5–2.5 m, MSR ≈ 4.7m and rip currents cause 25% of total incidents (Figure 1). In south coast regions surging waves and tidal cut-off, account for 8% and 10% of total recorded incidents respectively, showing an increased prevalence compared to west coast regions where the role of surging waves (3% of total incidents) and tide cut off (3% of total incidents) is less significant. When incidents are broken down to the number of individuals assisted/rescued (Figure 2), rip currents are shown to play a role in 71% of incidents occurring within Devon and Cornwall during the 2005 season. Offshore winds, sandbars, bednehm flow, high surf, strong winds, tidal cut-off and dumping waves individually represent no more than 15% of all incidents. Some of these environmental causes occur in conjunction with rip currents in 30% of incidents, suggesting risk to the beach user is often compounded with a combination of hazards i.e. large waves and littoral currents can drive the spatially unaware beach user into areas of increased rip current hazard.

To further understand the beach hazard characteristics and specifically the influence of rip currents in rescue incidents, individual locations were analysed (Table 1). This analysis included calculation of a coefficient of risk for each location for the 2005 season. This risk coefficient *IR* was derived through two statistics: (1) the average number of people estimated to be in the water per hour (P) between 10:00 and 17:00 hrs during the 2005 season; and (2) the average number of individuals assisted/rescued per hour (Re) at a specific location (calculated from the total number of insea assists/rescues per season divided by the number of hours in a season at each location). The ratio between these two statistics represents the probability of an incident occurring:

Table 1: Summary of beach safety and beach type statistics for selected locations in Devon and Cornwall.

ID	Location	P (hr^{-1})	Re ($indv.season^{-1}$)	IR ($\times10^{-2}$)	Re_{rip} ($indv.season^{-1}$)	IR_{rip} ($\times10^{-2}$)	Hb (m)	MSR (m)	D_{50} (mm)	Ω	RTR
					West coast						
1	Saunton Sands	-	-	-	-	-	-	7.9	0.19	7.1	6.3
2	Croyde	-	-	-	-	-	-	7.9	0.37	5.2	6.3
3	Sandymouth	31	102	0.324	98	0.321	0.7	6.8	0.36	6.3	4.5
4	Harlyn	80	13	0.005	0	0.000	0.3	6.5	0.43	3.5	6.5
5	Booby's Bay	21	2	0.005	0	0.000	0.6	6.5	0.39	4.8	4.3
6	Constantine Bay	48	201	0.378	191	0.376	0.6	6.5	0.39	4.8	4.3
7	Perran Sands	35	41	0.073	23	0.062	0.6	6.1	-	7.0	4.1
8	Perranporth	118	379	0.227	296	0.201	0.6	6.1	0.33	-	-
9	Chapel Porth	29	83	0.258	66	0.210	0.7	6.1	0.47	4.8	4.1
					South coast						
10	Challaborough	26	43	0.073	1	0.004	0.4	4.7	0.92	1.7	6.3
11,12	Bigbury (west,east)	29	5	0.013	2	0.007	0.2	4.7	0.30	4.9	6.3
13	Sedgewell Cove	33	40	0.088	5	0.015	0.3	4.7	0.32	4.6	6.3
14	Bantham	44	86	0.141	53	0.096	0.4	4.7	0.29	5.3	6.3
15	Torcross	8	20	0.178	0	0.000	0.1	4.3	4.20	0.5	8.6

P = average number of people insea per hour; Re = total number of individuals assisted per season; IR = Re./ P (risk ratio); Re_{rip} = total number of individuals assisted in rip related incidents per season; IR_{rip} = Re_{rip} / P (rip risk ratio); Hb = mean observed breaker height during 2005 season; D_{50} = grain diameter; Ω = dimensionless fall velocity (H_b/w_sT);RTR = relative tidal range (MSR/H_b)

$$IR = Re / P$$

The risk of rip current related incidents IR_{rip} was also calculated:

$$IR_{rip} = Re_{rip} / P$$

where Re_{rip} is the number of rip incidents per hour at each location. West coast beach locations 6, 3, 8 and 9 have the highest rip current risk of all RNLI patolled beaches, whereas sheltered west coast beaches (4) and south coast locations 10, 11, 12, 13 and 15 have the lowest values for rip current risk with only 8 rip current related incidents between them in 2005.

Beach Hazards

Reviewing the RNLI incident data, it is clear that the type and level of hazards vary with location. The beaches listed in Table 1 were chosen for further analysis as they represent the high and low risk extremes of the RNLI beaches within the study region, and contain a representative spread of the beach types present around the coast.

The exposed intermediate beaches on the west coast (2, 3, 5, 6, 8, and 9), having a $H_{s10\%}$ of approximately 2.5 to 3m, represent some of the highest rip risks, with values at locations 6 (Constantine) and 8 (Perranporth) reaching 0.376 and 0.201 (probability of rip related rescues per hour) respectively. Perranporth and Constantine also received the most incidents during 2005 with 379 and 201 individuals rescued, respectively.

The low rip current risk values consist of beaches located within sheltered areas of the west coast (location 4) and the south coast (see Figure 4). These areas have a reduced $H_{s10\%}$ due to the aspect of the coast. The powerful westerly Atlantic swell waves which are dominant throughout the year have to refract through 45-90º to arrive at the sheltered north and south facing beaches. Harlyn Bay (location 4) had an average of 80 individuals inseahr^{-1} during the season compared to 48 at the neighbouring Constantine Bay, but only 14 environmentally driven rescues occurred during the season as opposed to 201 at Constantine Bay. At south coast locations mean observed H_b was between 0.1m and 0.4m at patrolled beach locations 10, 11, 12, 13, 14 and 15 during the 2005 season. These locations had the lowest calculated rip current risk values. In some cases other environmental hazards were more prevalent. On the south coast, in combination with lower energy conditions, the dominant winds from the western quadrant blow offshore in many locations, increasing the risk of the beach user drifting offshore. Significant tidal cut off hazards are present at many locations where the large tidal range causes submerged high water beaches. The ease of beach access and characteristics of backshore geology control the severity of this hazard.

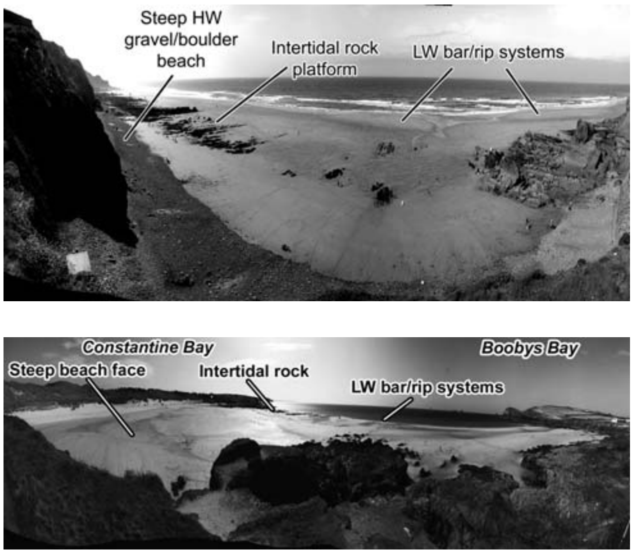

Figure 3. Annotated panoramic views of Sandymouth (above) and Constantine and Boobys Bay (below) at low tide.

Beach types and rip risks

The physical characteristics of the beach and its location within the hydrodynamic setting of the region play a key role in defining rip current hazards and risks to the beach user. The southwest coast of England displays a wide variety of medium to high energy beach types amongst varying tidal ranges.

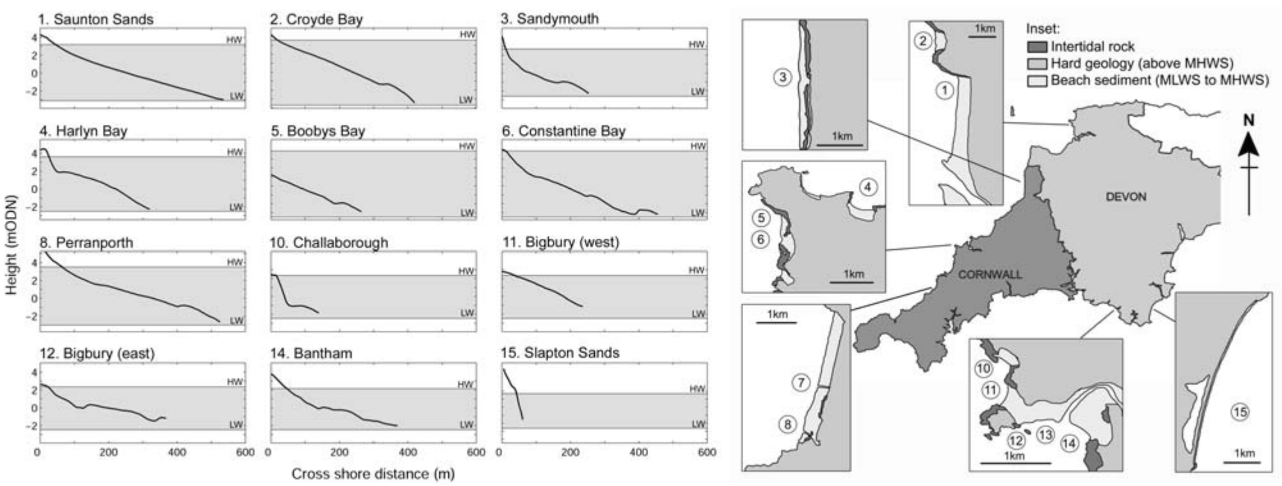

Figure 4. Summary of cross shore profiles and tide ranges at selected locations around Devon and Cornwall (height measured in meters above Ordnance Datum Newlyn), and schematic plan views of each site indicating beach shape, aspect of the coast and intertidal geology.

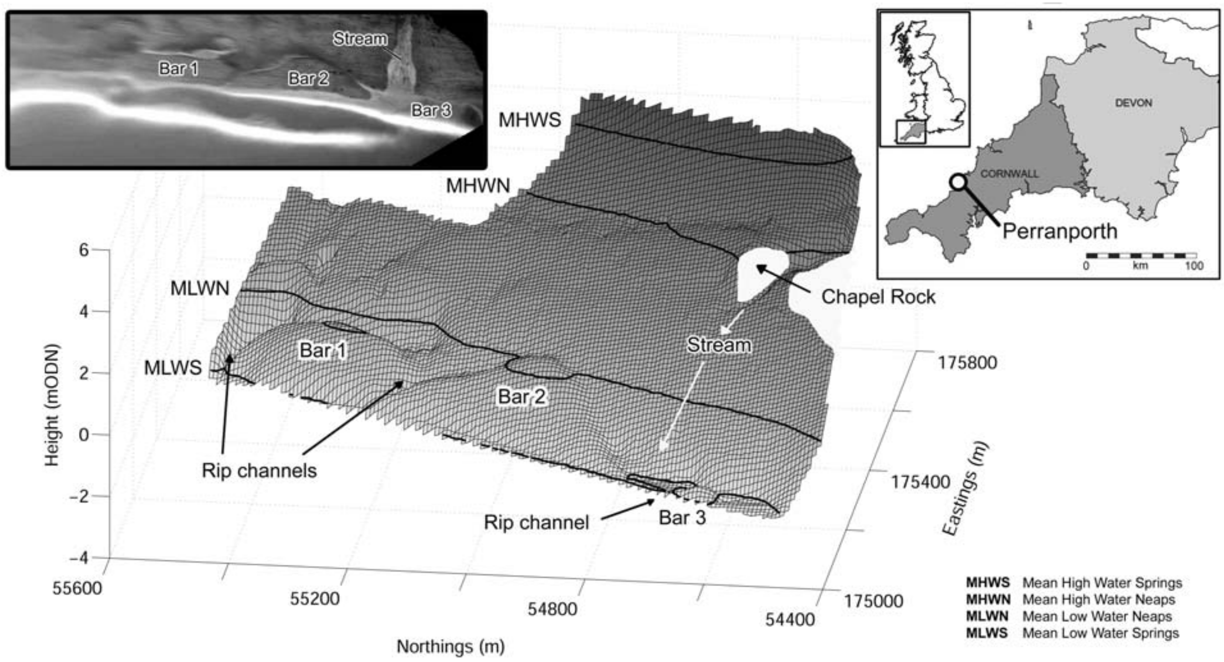

Figure 5. Digital Terrain Model of Perranporth Beach with mean tidal statistics and annotations marking main morphological features. Inset: Rectified timex image of low tide bar morphology and surf zone at Perranporth Beach from the Droskyn Argus camera station.

Ultra-dissipative beaches

Ultra-dissipative high energy surf zones like Saunton Sands (Ω=7.1 and RTR=6.3) that are not represented within previous Australian studies (MASSELINK and SHORT, 1993; WRIGHT and SHORT, 1984b), exhibit a very wide (≈500 m), low gradient, featureless intertidal profile with no significant bar morphology (Figure 4). Saunton Sands, characterised by a low gradient fine sand beach (D_{50}=0.19 mm), has an MSR of 7.9 m and shows very subdued intertidal morphology due to the cross shore translation of high energy surf zone processes during the tidal cycle. Intertidal zones of this width do not occur in high energy wave climates in Australian examples. Although there is no lifeguard service at Saunton Sands, it presents a lower risk to the water user due to the lack of intense rip current systems and the non barred, dissipative nature of its wide surf zone. Thus incident wave energy is greatly reduced when it reaches the bathing zone. Consequently it is popular with novice surfers.

Intermediate (Reflective/Dissipative) Beaches

The more common intermediate beach types, with large tidal ranges (MSR between 6.1 to 7.9 m) and an energetic wave climate, are represented by low tide terrace, low tide terrace and rip, and low tide bar/rip morphologies. They are characterised by a steeper, often coarse, more reflective high water beach face, a wide (400-600 m) subdued dissipative intertidal zone (swash bar sometimes present) and well developed intermediate low water bar and rip circulation systems (Figure 4). The beaches with the highest calculated rip current risk fall into the low tide bar/rip beach type (Constantine Bay, Perranporth, Sandymouth and Chapel Porth), with a Ω of between 4.8 and 7 and an RTR between 4.1 and 4.3.

Backshore geology and intertidal rock formations have a significant influence on the characteristics of the beaches of Devon and Cornwall. At both Sandymouth and Constantine Bay (Figures 3 and 4) these formations are fundamental in generating the beach hazards that are present. Sandymouth, with a gravel and boulder reflective high water beach, possesses an intertidal rock platform which topographically constrains circulation within the surf zone, consequently driving fixed rip current systems. The geological constraints at Constantine Bay act to influence surf zone circulation from high to low water, generating deep rip channels. These are especially severe at low water when the ebbing tide enhances rip current velocities, leading to the highest rip current risk in the region.

Other beach types associated with high rip current risk are those represented by Perranporth (Figure 5) and Chapel Porth (Figure 6). Both locations receive similar hydrodynamic forcing with a MSR of 6.1 m and an $H_{s10\%}$ of 2.5 m (DRAPER, 1991), and have a well defined often rhythmic unconstrained bar and rip morphology that is exposed at MLWS. During the survey period, the unconstrained rhythmic bar and rip morphology, present at many west coast beaches had a wavelength of 300-400 m and amplitude of 1.5-2 m. With an incident breaker height of 0.5-2 m, intense topographically driven rip systems can develop as narrow rip feeders travelling within the channels between the bars, creating high risk conditions for water users around low water at these locations (SHORT and HOGAN, 1994; MACMAHAN et al., 2006). Figure 5 and inset shows the low tide bar and rip morphology at Perranporth and a rectified timex image from the Perranporth Argus station, indicating the presence of a detached sub tidal rhythmic bar system. Rip hazards are enhanced at low water as the bars, accommodating beach users, are submerged during the flooding tide, activating morphologically constrained rip feeder currents in the lee trough placing the beach user at risk.

Reflective Beaches

The steep reflective beaches on the south, channel coast like Slapton Sands (Ω=0.5 and RTR=8.6) are coarse grained

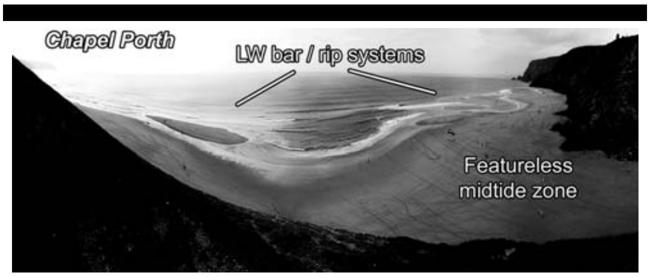

Figure 6. Annotated panoramic image of Chapel Porth at low tide.

(D_{50}=4.2 mm), narrow (≈70 m) and associated with plunging and surging breakers within a small surf zone. Dominated by wind waves (H_b=0.1 m), no significant rip current hazards present themselves.

Comparison of Australian and UK beaches

The beaches of southwest England possess a number of significant differences to those documented in previous Australian studies (WRIGHT et al., 1984a; WRIGHT and SHORT, 1984b; SHORT, 1986; MASSELINK and SHORT, 1993; SHORT, 2001; SHORT, 2006). Firstly, fine, wide, high energy ultra-dissipative beaches like Saunton Sands; secondly, steep reflective gravel beach types, like Slapton Sands of the protected south coast with a comparatively low Ω of 0.5 but a high RTR of 8.6; and thirdly, wide largely featureless, high energy intermediate beaches (Ω=4.8-7, RTR=4.1-4.3) with more developed high and low water morphology, are not well represented within the Australian coastal environment. These differences are generated largely by the coupling of a high energy wave climate and large tidal ranges in the UK. As a result, these beaches do not become tide dominated with a large tidal excursion. Also, the variation in coastal geology and the present and historic sediment supply to beaches constrains the level of hydrodynamic control on beach type.

Rare in the southwest but common to the UK (especially the east coast of England), ridge and runnel beaches and those modified with intertidal coastal structures are environments that have also received limited coverage within Australian beach type models (WRIGHT and SHORT, 1984b; MASSELINK and SHORT, 1993) but represent unique UK beach morphologies and associated hazards.

CONCLUSIONS

As beach visitor numbers increase in the UK, understanding the physical hazards and risks posed to the beach user within a national context becomes paramount. This will underpin deployment of safety resources and enable improved understanding of the national beach environment that contributes to thousands of rescues annually. The south and southwest of England beach hazards are posed by a number of environmental factors; strong/offshore winds, sandbars, bednehm flow, large waves, tidal cut off and dumping/surging waves, but the most significant is rip currents. Based on this study of the beach types, hazards, rip current characteristics and lifeguard rescue statistics the following conclusions can be drawn.

1) Rip currents represent the greatest environmental threat to the insea beach user. This threat can be compounded by a series of hazards working together.

2) There is a significant variation in beach hazards and their severity depending on the nature of the hydrodynamic conditions and beach type. The reflective low tide terrace and rip and intermediate, low tide bar/rip morphologies as described by MASSELINK and SHORT (1993) possess the high risk rip current systems, that are most active during wave heights of 0.5-2 m after which the beaches are often closed to bathers.

3) Surf zone morphologies are not as predictable as in previous Australian studies (SHORT, 1994). There is a great variation in surfzone characteristics due to beach boundary and intertidal geology, often constraining sand and water movement and enhancing rip current systems. With high energy surf zones and large tidal ranges the southwest of England experiences different hydrodynamic forcing than Australia, thus generating beach types unique to this climate.

4) Moderate energy (0.5-1.5 m) Atlantic swell waves during spring and summer enable the development of rhythmic bar morphology on the intermediate beaches at the low water stand, generating morphologically controlled rip current systems.

5) Large tidal ranges introduce hazards such as tidal cut off through high water levels and horizontal speed of shoreline movement, and enhance rip current velocities on the ebbing tide.

ACKNOWLEDGEMENTS

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