Proceedings of the 2nd International Conference on Environmental Interactions of Marine Renewable Energy Technologies (EIMR2014), 28 April – 02 May 2014, Stornoway, Isle of Lewis, Outer Hebrides, Scotland. www.eimr.org

EIMR2014-204

Perceptions of the Inshore Wave Resource by Beach Water-Users in the lee of Wave Hub

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ABSTRACT

Recreational water-users are of great economic importance to Cornwall, UK. Concerns over the potential impact of the Wave Hub renewables test site in Cornwall on inshore recreational wave amenity has prompted research into potential changes to wave height and period. There is little existing research however to indicate what surf conditions are 'preferred' by various beach water-user groups, nor how they perceive the inshore wave resource. It is therefore unclear how likely they are to be affected by, or if they will correctly perceive, any changes to the wave climate caused by devices at Wave Hub or future renewables projects. Questionnaire data from 403 water-users collected at two beaches in the lee of Wave Hub reveal the characteristics of water-users in the region, including ideal conditions for water recreation, and their perception of the abundance of the wave resource.

INTRODUCTION

Recreational water-users such as surfers and bathers are of great economic importance to Cornwall, UK, bringing £300 million of tourism a year to the region [1]. In 2007 a petition signed by 500 surfers raised concerns that wave energy converters proposed to be trialled at the Wave Hub (www.wavehub.co.uk) marine renewables test site in Cornwall, might affect water recreation and tourism on the beaches in its lee [2]. The primary concerns of this stakeholder group were that inshore wave height might be reduced and that effects on wave period are unknown. Although there has since been a number of modelling studies to predict changes to inshore wave height and period from hypothetical device arrays at Wave Hub [including 3, 4, 5], there is little existing research to indicate what surf conditions are 'preferred' by various beach water-user groups, nor how they perceive the inshore wave resource. Near monochromatic waves at the peak or lower end of the frequency spectrum, and of heights between 1-4 m, are thought to be favoured by surfers and were of concern to those involved in the Wave Hub consultations [4, 5]. Although these studies provide some insight into surfer preferences, the aforementioned conditions are broad ranging and were derived from the opinions of relatively few individuals. The range of wave conditions of most value to surfers therefore remains unclear, and of equal concern, the conditions preferred by other water-user groups are completely unknown. It is therefore uncertain how likely they are to be affected by, or if they will correctly perceive, any changes to the wave climate caused by devices at Wave Hub (set to be installed 2014-15 [6]) or future renewables projects.

METHODOLOGY

Randomly sampled questionnaire data, collected on 36 survey dates between April 2013 and March 2014, are presented here. Perranporth and Porthtowan beaches on the North Coast of Cornwall, UK, were chosen as the study sites as they lie in the middle of the area predicted to experience the greatest reduction in wave heights from Wave Hub (if any occurs). On average, 11 questionnaires were completed on each visit, with a total sample of n = 403. Participants were asked about their use of the sea, as well as being asked to state their preferred wave height and period for water recreation. They were also asked what they perceive to be the annual mean breaker height, the probability of waves breaking over 6ft (1.83 m), and the probability of 'ideal' wave conditions for water use occurring on any given day. Water-user observations of breaking wave height and period tend to underestimate measured values, and the perception of breaker characteristics varies between different groups of water-users [7]. Nearshore wave buoy measurements at Perranporth beach (collected in 10 m water depth and transformed to breaking height using linear theory), were compared to concurrent visual observations of mean breaker height and period made by each participant, in order to determine a mean perception ratio (visual/measured) for each of the key water-user groups identified (see table 1).

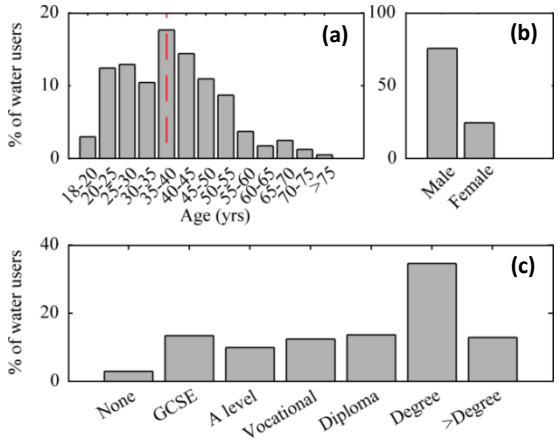

Figure 1. Demographics. (a) Age; dashed line is median age (b) Gender (c) Highest educational qualification.

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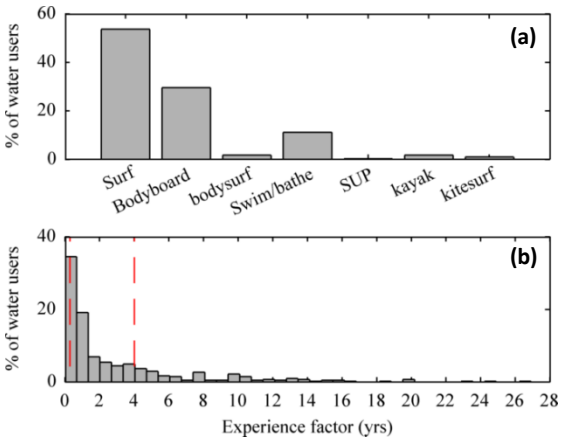

Figure 2. Water use statistics. (a) Preferred water activity (b) Experience factor; dashed lines are thresholds between novice, intermediate and expert water-users respectively (25th and 75th percentile).

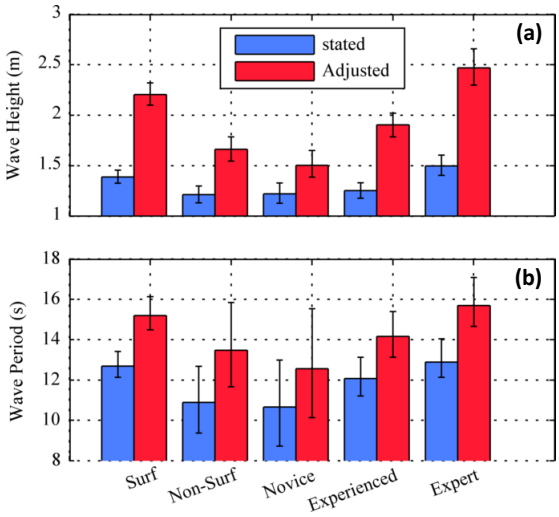

Figure 3. Stated and adjusted wave preferences for different beach water-user groups. Bars are 95% confidence bounds.

Stated preferences and perceptions were subsequently adjusted using these ratios, in order to represent 'measured' breaking conditions. A full description of the method is given in [7].

Table 1. Mean perception ratios (visual/measured)

	surf H_s *ratio*	*non-surf* H_s *ratio*	*surf* $T_{1/3}$ *ratio*	*non-surf* $T_{1/3}$ *ratio*
Novice	0.75	0.83	0.79	0.81
Intermed.	0.63	0.70	0.87	0.81
Expert	0.59	0.62	0.81	0.81

OBSERVATIONS

Characteristics of the population

Figures 1 and 2 indicate that male surfers make up the vast majority of the population of water-users at the two sites; body boarding and swim/bathing are the next most popular activities respectively. The median age of all water-users is 38 years old, and the group is well educated compared to national figures. 47% have a degree or higher level qualification, compared to the national figure of 27% [8]. To categorise water-users, each individual was defined as either novice (25% of the sample), intermediate (50%) or expert (25%) at their preferred water activity by determining an 'experience factor', calculated as the product of the number of years each individual has participated for and the typical percentage of days in a year they participate [7] (see figure 2), and they were divided by activity into surf and non-surf categories (approximately 55% and 45% of the sample respectively).

Preferred wave conditions

The range of preferred wave conditions for recreation is surprisingly small for all of the sampled water-user groups (see figure 3). The mean preferred wave height and period stated by participants was H_s 1.3 m (std. dev. 0.5 m) and $T_{1/3}$ 12 s (std. dev. 4.8 s), respectively, and only small differences in preference existed between the groups. The stated wave preferences were then adjusted to account for different perceptions of waves, using the perception ratios outlined earlier. The range of preferred conditions then increased, and there were larger significant differences between the mean preferred breaking wave height of novice (H_s 1.5 m), intermediate (H_s 1.9 m) and expert (H_s 2.5 m) water-users, as well as surfers (H_s 2.2 m) and non-surfers (H_s 1.7 m). Preferred wave period increased when it was adjusted (mean $T_{1/3}$ 14 s) and was not significantly different for any of the water-user groups. To determine which wave frequencies contain the most energy, and are therefore most likely to be targeted for energy extraction, half-hourly wave spectra collected in 10 m water depth at Perranporth between 19th Dec 2006 and 31st Jan 2014 were summed to find the overall peak frequency. Figure 4 shows total spectral density plotted against period (1/freq.) for all available data. This indicates that the stated preferred wave period (12.1 s) is approximately equal to the peak period of the summed spectra (12.5 s), and the adjusted preferred period (14.4 s) is only slightly higher than the peak period.

Perception of wave resource

To investigate the perceived abundance of wave energy in the study region, participants were asked to estimate the annual mean wave height, as well as how often they think 'large' wave conditions (arbitrarily defined as H_s > 6 ft. (1.83 m)) occur as a percentage of days in a typical year. After adjusting for differences in wave perception as previously described, the perceived mean breaking wave height was H_s 1.8 m (std. dev. 0.6 m) and did not vary significantly between the different water-user groups. The measured mean wave height at breaking is remarkably close to this value, at H_s 1.75 m for both sites (19th Dec 2006 - 31st Jan 2014). Large wave conditions were perceived to occur on 34% of days (mean value. Std. dev. 19%). To determine an equivalent 'measured' probability of large waves to compare to each persons perceived probability, differences in the perception of wave height must

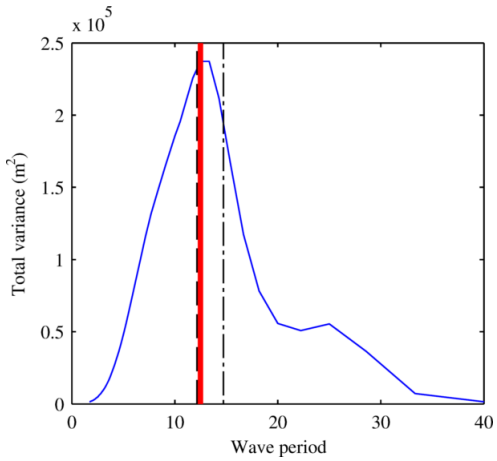

Figure 4. Summed variance density spectrum from 6.9 years of half hourly spectra at Perranporth buoy (10 m depth). Solid line indicates the peak period; the dashed and dot-dashed lines are the stated and adjusted mean preferred period, respectively.

again be accounted for. The perception ratio for each water-user group (see table 1) was used to scale the arbitrary threshold (1.83 m) to an adjusted threshold for each individual. The number of days when measured daily-mean H_b was greater than their adjusted threshold was then counted, yielding a measured probability. The difference between measured and perceived probability was then calculated to indicate whether individuals under or overestimated the occurrence of large waves. On average participants overestimated the occurrence of large waves by 19% (std. dev. 18%), indicating that they perceive the wave climate to be more energetic than it actually is.

The perceived abundance of 'ideal' wave conditions for recreation varied. There were significant differences between novice, intermediate and expert water-users, who perceived ideal waves to occur on 48%, 37%, and 27% of days in a typical year, respectively, as well as non-surfers and surfers who perceived ideal waves to occur on 43% and 32% of days, respectively. Calculating the measured probability of ideal conditions for each group is beyond the scope of this study, as it is a function of height, period, and breaker type, and is subjective. Regardless, the results indicate that expert surfers (18% of the sample) perceive ideal waves to happen infrequently (25% of days), while novice non-surfers (17% of the sample) perceive that ideal waves occur on half of all days in a typical year.

SYNTHESIS

Although water-users appear to overestimate the abundance of wave energy on the whole, a concerning finding is that the stated preferred wave period of all water-users in the region is approximately equal to the peak period, associated with the bulk of available wave energy (see figure 4). It is likely that WEC's will extract energy efficiently over a finite range of frequencies (frequency dependent extraction), due to device resonance and tuning to target energy at peak frequencies [3]. This indicates there is a potential clash of interest between device developers and water-users, both predominantly interested in waves of ~ 12 s period. If water-users learn that energy extraction will target waves of around 12 s, there may be enhanced opposition from this stakeholder group. Surfers and/or expert water-users are the groups most likely to anticipate negative impacts to recreational wave amenity, as they already perceive ideal wave conditions for recreation to be scarce [9]. Therefore the low level of likely height reduction (which is predicted to be < 0.5% in a scenario of 30% energy extraction [3]) needs to be clearly conveyed to water-users to avoid opposition.

ACKNOWLEDGEMENTS

Thanks to all the participants that gave their time to take part in this study. Particular thanks go to Eleanor Woodward, Claire Earlie, and Emma Rendle for their enthusiastic help in collecting data.

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