

## Risk behaviors and self-reported illnesses among Pacific Northwest surfers

Anna K. Harding, David L. Stone, Andres Cardenas and Virginia Lesser

### ABSTRACT

Although surfers have high incidental exposure to marine waters, no studies have investigated if surfer risk behaviors (such as surfing during advisories, near an outfall, during a rain event, or use of personal protective equipment) increase or decrease the risk of acquiring waterborne illnesses. We used a web-based survey to assess the association between risk-based behaviors and self-reported illnesses among Pacific Northwest surfers. Commonly reported illnesses include: ear infection or discharge (38%), sore throat or a cough (28%), diarrhea (16%), fever (10.5%), and vomiting (7%). Surfing often during rain events was associated with an increased likelihood of diarrhea (OR = 2.7; 95% CI: 1.4–5.47), sore throat (OR = 1.26; 95% CI: 1.01–2.05), and ear infection (OR = 1.39; 95% CI: 1.01–2.32). Surfing during a health advisory was associated with increased likelihood of diarrhea (OR = 1.94; 95% CI: 1.03–4.64) and sore throat (OR = 2.32; 95% CI: 1.23–4.40). Other behaviors associated with increased illnesses include body surfing, surfing near an outfall, frequency of surfing, and use of ear plugs. Approximately 40% of surfers were unaware if they had surfed during an active health advisory and 29% knowingly surfed during advisories, suggesting the need to engage this population about potential harm and behaviors that may increase health risk.

**Key words** | behavior, marine water, recreational exposure, recreational water illness, risk, surfer

**Anna K. Harding** (corresponding author)

**Andres Cardenas**

School of Biological and Population Health Sciences,  
College of Public Health and Human Sciences,  
100 Milam Hall,  
Oregon State University,  
Corvallis, OR, 97331,  
USA  
E-mail: [anna.harding@oregonstate.edu](mailto:anna.harding@oregonstate.edu)

**David L. Stone**

Department of Environmental and Molecular Toxicology,  
327 Weniger Hall,  
Oregon State University,  
Corvallis, OR, 97331,  
USA

**Virginia Lesser**

Department of Statistics,  
Survey Research Center,  
46 Kidder Hall,  
Oregon State University,  
Corvallis, OR, 97331,  
USA

### INTRODUCTION

Surfers are an under-studied population in the Pacific Northwest and the USA with regard to risk behaviors and illnesses. Surfers may comprise a disproportionately large fraction of marine recreationalists, particularly in some regions of the USA, including the Pacific Northwest and California coastal areas (Turbow *et al.* 2008). This population is at potential risk from exposure to fecal contamination in marine waters, particularly if engaged in behaviors such as surfing during posted advisories or after rainfall events, when marine waters are more likely to be contaminated with fecal bacteria.

Coastal waters are frequently contaminated with pathogenic organisms from a variety of natural and anthropogenic sources. Contamination may be more prevalent along beaches and near shore areas that receive high recreational use (Turbow *et al.* 2003; Dwight *et al.* 2004). Exposure to pathogens in recreational waters is associated with an

increased risk of gastrointestinal (GI) illness, respiratory, ear, eye, and skin rashes or infections, meningitis, and hepatitis (Cabelli *et al.* 1983; Dewailly *et al.* 1986; Corbett *et al.* 1993; Kay *et al.* 1994; Prüss 1998; Haile *et al.* 1999; Wade *et al.* 2003; Dwight *et al.* 2004). In particular, Haile *et al.* (1999) reported higher risk of fever, chills, ear discharges, vomiting, and coughing associated with swimming in ocean water receiving untreated stormwater runoff. Although enterococcus density appears to be the indicator most strongly correlated with gastrointestinal illness among bathers in recreational waters (Arnore & Walling 2007), other studies examining the link between health effects and pathogen sources have not been conclusive (Perez Guzzi *et al.* 2000; Colford *et al.* 2007). In 1997, the EPA began the Beaches Environmental Assessment and Coastal Health (BEACH) Program in response to increased concern over bacterial and pathogen-induced disease

among recreational users in fresh and marine waters (USEPA 2002).

Surfing represents a higher risk activity when compared with other aquatic recreational activities such as wading or swimming, given the frequency of unanticipated head submersions, chaotic wave activity and the potential for exposures of longer duration (Turbow *et al.* 2008; Tseng & Jiang 2012). Even when comparing illnesses between swimmers and non-swimmers, Colford *et al.* (2012) found significant increases in diarrhea for swallowing water and other outcomes in swimmers compared to non-swimmers. Exposure among swimmers (body immersion, head immersion, swallowed water) was associated with increasing risk of gastrointestinal illness. Although the routes of exposure to waterborne pathogens are identical for surfers and swimmers, surfers are likely to have higher exposure compared to swimmers by virtue of more frequent and longer contact with fecal contaminated water (Dwight *et al.* 2004; Schijven & de Roda Husman 2006; Stone *et al.* 2008). Stone *et al.* (2008) found that the mean exposure magnitude and frequency were 170 mL of water ingested per day and 77 days spent surfing per year, respectively, which is markedly higher than those for swimmers and divers. This ingestion amount compares to an average amount of water swallowed by recreational swimmers who are children and adults to be 37 mL and 16 mL, respectively (Dufour *et al.* 2006), and by recreational and occupational divers who ingest 9 and 9.8 mL of marine water per dive, respectively (Schijven & de Roda Husman 2006). Estimates of water intake for surfers were markedly higher (mean = 170 mL/day) than those for swimmers and divers. Despite the cold annual water temperatures (13 °C), 57 Oregon beaches are used year round for surfing, with the primary surfing activity occurring from fall through spring, which corresponds to the majority of rainfall events throughout the year (Benedict & Neumann 2004). Oregon has 362 miles of coastline, with public access to all of the beaches.

In 2002, the Oregon Beach Monitoring Program (OBMP) began sampling near shore marine waters and freshwater outfalls for the presence of fecal bacteria using enterococci as an indicator organism. From May through September, ocean water is sampled by the OBMP either once a week, every two weeks, or monthly based on the priority ranking of the beach (Oregon Health Authority (OHA) 2013). The priority is determined by beach use, pollution

hazards, previous monitoring results, and input from coastal stakeholders. The acceptable swimming associated gastrointestinal (GI) illness rate of 1.9% or 19 illnesses per 1,000 swimmers is calculated at a steady state geometric mean indicator density of 35 CFU/100 mL or a single sample density of 158 CFU/100 mL which corresponds to EPA's 'Moderate Full Body Contact Recreation' category (USEPA 1986, 2004). The latter single sample density is currently the Oregon action level used to issue an advisory, and resampling occurs within 96 hours if the sample density is exceeded, except during winter months (OHA 2013). Oregon Beach monitoring data from 2002 to 2005 showed that one-third of the 52 beach locations had enterococci levels exceeding Oregon's action level (Neumann *et al.* 2006). Previous research indicates that while the risk of excess GI illness is not high with surfers in Oregon coastal waters, this group may not be adequately considered in the context of health advisories, due to their higher exposure levels (Stone *et al.* 2008).

Recreation that involves marine water contact is an extremely popular activity (Turbow 2009), and advisories are not uncommon occurrences. Between 2008 and 2013, there were 357 total advisory days issued for elevated enterococci detections on the Oregon coast (OHA 2013; NRDC 2013). However, little is known about the public's willingness to accept risks during swimming or surfing (Boehm *et al.* 2009) or the extent to which surfers are aware of health advisories and comply with recommendations to avoid water contact. Previous studies have reported acute and chronic conditions among surfers, which include surfing injuries, lacerations, sprains, fractures, otologic issues, and sun exposure (Nathanson *et al.* 2002; Zoltan *et al.* 2005). No studies to date, however, have investigated whether or not surfer risk behaviors (such as surfing during advisories, surfing near an outfall, surfing during a rain event, use of personal protective equipment (PPE)) may increase or decrease the risk of acquiring waterborne illnesses. This study addresses an important knowledge gap about surfer risk behaviors and to the study of illness in recreational marine waters. Although regional in focus, this study has broad implications for surfers and marine bathers worldwide, as it captures risk behaviors and self-reported illnesses that are likely transferable among different populations and locations.

## METHODS

### Survey design and development

To obtain information on risk behaviors and self-reported illnesses using a cross-sectional study design and point prevalence for the illnesses, we developed a web-based questionnaire with the assistance of Oregon State University's Survey Research Center (see Appendix, available online at <http://www.iwaponline.com/wh/013/231.pdf>). We used previously validated swimmer-related questionnaires (Colford *et al.* 2005) and questions specifically tailored to surfers. The questionnaire collected information in four areas: exposure assessment, risk behaviors, demographics, and risk perception. For more information on the questions related to exposure assessment, see Stone *et al.* (2008). Frequency was based on the number of surfing events per year or month. Risk behaviors assessed by participants included: (1) surfing during a posted advisory; (2) surfing 5 days prior to or following a rain event; (3) surfing near an outfall; (4) body surfing; (5) surfing with a skin abrasion; (6) incurring cuts or injuries when surfing; (7) showering after surfing; and (8) use of personal PPE, such as ear plugs, goggles, and wet suits. Demographic information collected included residency (Oregon or visitor), city and county of residence, age, gender, occupation, income, self-reported skill as a surfer (experience in years), and location of beaches used for surfing.

The questionnaire was pilot tested with a group of 25 surfers prior to conducting the study, and adjustments were made to the questionnaire based on the feedback that was received from the pilot group. The study was approved by Oregon State University's Institutional Review Board for the protection of human subjects, Protocol # 3503, dated April 7, 2007.

### Participant recruitment

The questionnaire was posted on a secure OSU site and linked to the Surfrider Foundation ([www.surfrider.org/oregon/](http://www.surfrider.org/oregon/)) and Oregon Surf ([www.oregonsurf.com](http://www.oregonsurf.com)) websites. The enrollment goal was to obtain 500 questionnaires, based on the estimate of 500 members in the Surfrider organization (which may represent 5–10% of the surfer population in Oregon). The study was restricted to adults 18 years of age and older; however, no restrictions were made based on race,

gender, or other demographic characteristics. Informed consent from participants was handled through introductory text which read, 'If you are 18 years or older and the above description fits your situation, please indicate your agreement to participate in the questionnaire by clicking CONTINUE to start the questionnaire.' Thus, participants provided their consent through completion of the questionnaire. Participants were able to print the information related to informed consent and study description, so that they can contact the study investigators at any time.

Participants were recruited into the study using several strategies. First, the online questionnaire was posted on the Surfrider Foundation (<http://www.surfrider.org/oregon/>) and Oregon Surf (<http://www.oregonsurf.com>) websites with agreement from representatives of both organizations. Visitors to each of these websites saw a brief announcement about the questionnaire and had easy access to the questionnaire website. Participants were primarily recruited by self-visitation to these websites, and included participants from both Oregon and Washington state. Although we had thought the survey would draw only participants from Oregon, because the survey was posted on the Surfrider website which draws interest from both Washington and Oregon, the participants ended up being from the Pacific Northwest rather than solely from Oregon. In addition, coastal surf shops were mailed a letter introducing the study and an informational flyer was included that directed potential participants to either the Surfrider or the Oregon Surf websites. This letter requested the assistance of shop owners to post the flyer and assist the researchers in the recruitment by encouraging shop patrons to go to the websites to participate in the survey. These mailings were followed up by a phone call to answer any questions or concerns about the survey. Potential participants were not required to be paid members of the Surfrider Foundation to participate in the survey.

### Data analysis and storage

Descriptive statistics including proportions or means along with standard errors were calculated for all variables of interest in the study. The proportion of surfers who reported surfing during an advisory, not surfing during an advisory, or not knowing if they surfed during an advisory, was

calculated across three categories of self-reported illnesses and a chi-square test was used to evaluate the association. In addition, univariate and multivariate association of covariates with individual self-reported illnesses were evaluated using unadjusted and adjusted logistic regression models, respectively. Univariate analyses were carried out using independent logistic regression models for each predictor and health outcome and multivariate logistic regression models were used to adjust for all significant risk factors on each health outcome. Odds ratios (ORs) and 95% confidence intervals (CIs) were computed to evaluate and quantify the potential association of risk behaviors to self-reported illnesses. A backward elimination procedure was used to build five final multivariate logistic regression models for each health outcome (fever, diarrhea, sore throat/cough, ear infection/discharge, and vomiting) in relationship to risk behaviors. For the backward elimination procedure, all risk behaviors were initially included in a multivariate model. The variable with the highest  $p$ -value is removed and the model is refit with all remaining variables. Another non-significant variable is then eliminated from this model. The model is refit and the process is repeated until arriving at a final model that includes only significant predictors (Myers 1990). All statistical tests were two-sided and a two-tailed  $p$ -value of  $<0.05$  was used as threshold for statistical significance. Data management and analysis were carried out using Stata version 12.1 (StataCorp, College Station, Texas).

Participant responses were stored on a secure server managed by OSU's Survey Research Center. Data collected from participants did not include any names or email addresses that might allow for identification of participants. Responses were entered into a database until no more completions were submitted and the desired number of responses had been received. Staff at the Survey Research Center monitored data collection and forwarded the database to the investigators after data cleaning and preliminary analysis had been completed.

## RESULTS

The set of completed questionnaires was submitted from primarily males (89%), who were white (91%), and had some

type of college education (93%). A total of 510 questionnaires were received and the greatest proportion of non-responses were observed for the question regarding the use of earplugs (30%), but most variables were missing information for less than 10% of the responses. Survey participants ranged between 15 and 64 years of age, with a mean age of 33 years. Surfing experience ranged from less than one year to 51 years, with a mean surfing experience of 12 years. Participants reported annual incomes evenly spread between less than \$15,000 to over \$100,000. Five illnesses were most commonly reported: ear infection or discharge (38%), sore throat or a cough (28%), diarrhea (16%), fever (10.5%), and vomiting (7%), summarized in Table 1.

### Self-reported risk behaviors

In addition to surfing-related illnesses, surfers were asked whether they have surfed during the time a health advisory had been issued. The majority of surfers, nearly 40%, were not sure whether they surfed during a health advisory and 28% reported surfing at the time a health advisory had been issued (see Table 2). Less than a third (32%) reported not surfing during the period of a health advisory. A significant association was observed between the number of self-reported illnesses and surfing during a health advisory ( $\chi^2$   $p$ -value = 0.003) (see Figure 1). Among those who reported no illnesses related to surfing ( $n = 216$ ), 20% surfed during a health advisory, 37% have never surfed during an advisory, and 43% were not sure. For surfers who reported experiencing one or two illnesses ( $n = 134$ ), 32% surfed during a health advisory, 28% never surfed during an advisory, and 40% were not sure. For those experiencing three or more illnesses ( $n = 141$ ), 44% surfed during a health advisory, 32% reported not surfing during an advisory, and 24% were not sure (see Figure 1).

Results of the self-reported behaviors are summarized in Table 2 and were also estimated across self-reported illness. Most surfers reported surfing during a rain event often (41.9%) or sometimes (50.2%), while only a few reported never surfing during a rain event (7.9%). The majority of participants reported sometimes surfing with a cut on their skin (55.56%) or doing this often (35.7%), but only a few reported never doing it (8.7%). About half (51.2%) of respondents

**Table 1** | Overall sample characteristics (*n* = 492)

Characteristics	<i>n</i>	Frequency	Percentage (%)
Gender	492		
Male		438	89.0
Female		54	11.0
Race/Ethnicity	492		
White/Caucasian		446	90.7
Black/African American		1	0.2
Asian		4	0.8
Hawaiian or Pacific Islander		4	0.8
American Indian/Alaska Native		3	0.6
Mixed race		20	4.1
Other		14	2.8
Education	492		
No high school		4	0.8
High school		29	5.9
Some college		160	32.5
Bachelor's degree		184	37.4
Master's		85	17.3
Doctorate		27	5.5
Other		3	0.6
Income	480		
Less than \$15,000		49	10.2
\$15,000 to \$34,000		83	17.3
\$35,000 to \$49,999		72	15.0
\$50,000 to \$74,999		123	25.6
\$75,000 to \$99,999		70	14.6
\$100,000 to \$124,999		38	7.9
\$125,000 or more		45	9.4
Surfing-related illnesses experienced	467		
Ear infection/Discharge		176	37.7
Sore throat/Cough		132	28.2
Diarrhea		76	16.3
Fever		49	10.5
Vomiting		34	7.3
Continuous variables		mean, (median)	
		[min-max]	
Age (years)	488	33, (32)	[15-64]
Overall surfing experience (years)	492	12, (8)	[0.5-51]

never surfed near a sewage outfall. However 16.1% reported often surfing near a sewage outfall, and 32.6% reported doing this sometimes. About a third of surfers (30.6%)

reported showering right after surfing while the majority of participants did not (69.4%). A small proportion of surfers self-reported wearing earplugs (9.1%) while surfing but the majority reported not using them (90.9%). The frequency of surfing in a month was relatively high with only 31% of participants reporting surfing once or twice a month, 24.7% surfed 3-4 times a month, 27.3% surfed 5-10 times during a month, and 17% surfed more than 10 times in a month. Lastly, about a third (33%) of surfers reported engaging in body surfing.

### Multivariate analyses

Table 3 summarizes results from the multivariate logistic regression models fit to these data.

#### Fever

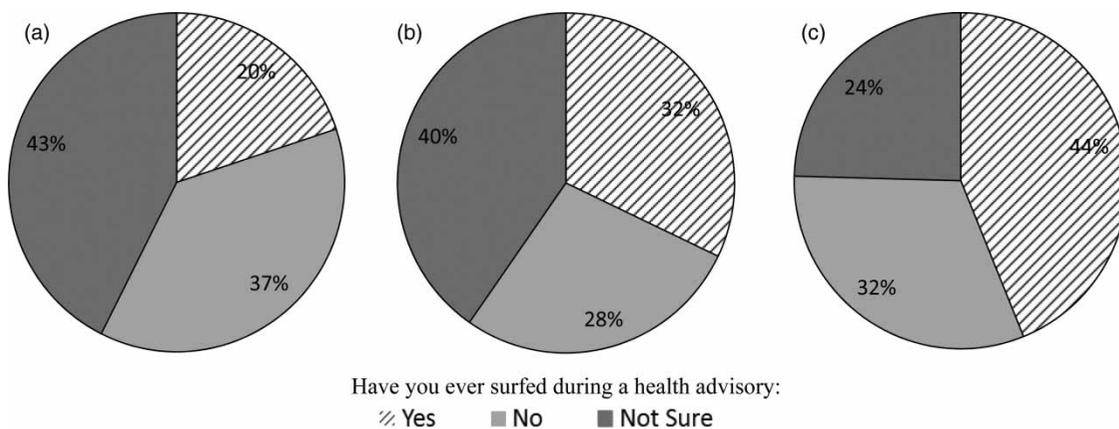
Individuals who wore earplugs had 3.8 times the odds of reporting a fever related to surfing as compared to individuals who did not wear earplugs (OR = 3.82, 95% CI: 1.91-7.67). Surfers who practiced body surfing had 2.4 times greater odds of reporting a fever as compared to individuals who did not body surf (OR = 2.42, 95% CI: 1.24-4.74). The frequency of surfing was also significantly associated with experiencing a fever. Individuals who surfed more than 10 times per month had 7.2 times the odds of reporting a fever as compared to surfers who only surfed once or twice a month (OR = 7.22, 95% CI: 2.68-19.43).

#### Diarrhea

Individuals who surfed during a health advisory had 1.9 times the odds of experiencing diarrhea compared to individuals who did not surf during an advisory (OR = 1.94, 95% CI: 1.03-4.64). Individuals who surfed often during a rain event had 2.7 times greater odds of having diarrhea compared to individuals who sometimes surfed during rain events (OR = 2.74, 95% CI: 1.37-5.47). Surfers who wore earplugs had a 2.6 times greater odds of suffering diarrhea as compared to individuals who did not wear earplugs (OR = 2.63, 95% CI: 1.00-7.16). Body surfing also increased the odds of reporting diarrhea by 2.4 times (OR = 2.40, 95% CI: 1.25-4.59), compared to individuals who did not engage

**Table 2** | Estimated sample numbers and proportions for self-reported risk behaviors across self-reported illnesses evaluated in the cross-sectional sample

		Self-reported illnesses					
	During a rain event	<i>n</i> (%)	Fever	Diarrhea	Sore throat/Cough	Ear infection/Discharge	Vomiting
Risk behaviors	Often	203 (41.9%)	28 (58.4%)	47 (62.7%)	67 (51.1%)	93 (53.4%)	17 (51.5%)
	Sometimes	243 (50.2%)	16 (33.3%)	22 (29.3%)	61 (46.6%)	76 (43.7%)	16 (48.5%)
	Never	38 (7.9%)	4 (8.3%)	6 (8.0%)	3 (2.3%)	5 (2.9%)	0
With a cut on your skin	Often	164 (35.7%)	23 (51.1%)	40 (55.5%)	5 (4.0%)	77 (45.8%)	19 (59.4%)
	Sometimes	255 (55.6%)	21 (46.7%)	29 (40.3%)	64 (51.0%)	86 (51.2%)	12 (37.5%)
	Never	40 (8.7%)	1 (2.2%)	3 (4.2%)	5 (4.0%)	5 (3.0%)	1 (3.1%)
Near a sewage outfall	Often	39 (16.1%)	11 (36.7%)	16 (34.8%)	21 (26.9%)	23 (24.5%)	6 (27.3%)
	Sometimes	79 (32.7%)	12 (40.0%)	15 (31.6%)	28 (35.9%)	38 (40.4%)	9 (40.9%)
	Never	124 (51.2%)	7 (23.3%)	15 (32.6%)	29 (37.2%)	33 (35.1%)	7 (31.8%)
During health advisory	Yes	140 (28.5%)	18 (37.5%)	33 (40.0%)	52 (40.0%)	66 (37.9%)	16 (47.1%)
	No	157 (32.0%)	16 (33.3%)	18 (24.0%)	28 (21.5%)	52 (29.9%)	11 (32.3%)
	Not sure	194 (39.5%)	14 (29.2%)	24 (32.0%)	50 (38.5%)	56 (32.2%)	7 (20.6%)
Shower after surfing	Yes	151 (30.6%)	18 (36.7%)	22 (29.0%)	37 (28.0%)	49 (27.8%)	25 (73.5%)
	No	343 (69.4%)	31 (63.3%)	54 (71.0%)	95 (72.0%)	127 (72.2%)	9 (26.5%)
Use of PPE	Ear plugs						
	Yes	33 (9.1%)	16 (34.8%)	10 (17.5%)	9 (9.5%)	21 (16.9%)	2 (8.0%)
No	328 (90.9%)	30 (65.2%)	47 (82.5%)	86 (90.5%)	103 (83.1%)	23 (92.0%)	
Other activities	Frequency of surfing						
	Once or twice a month	153 (31.0%)	11 (23.4%)	16 (21.6%)	31 (23.7%)	40 (23.7%)	10 (31.2%)
	3–4 times a month	122 (24.7%)	6 (12.8%)	15 (20.3%)	28 (21.4%)	39 (23.1%)	3 (9.4%)
	5–10 times a month	135 (27.3%)	13 (27.6%)	24 (32.4%)	41 (31.3%)	55 (32.5%)	8 (25.0%)
	More than 10 times	84 (17.0%)	17 (36.2%)	19 (25.7%)	31 (23.6%)	35 (20.7%)	11 (34.4%)
	Body surfing						
Yes	150 (33.0%)	23 (51.1%)	34 (47.2%)	61 (48.8%)	58 (36.3%)	16 (50.0%)	
No	305 (67.0%)	22 (48.9%)	38 (52.8%)	64 (51.2%)	102 (63.7%)	16 (50.0%)	

**Figure 1** | Proportion of surfers who surfed during a health advisory, summarized by the number of surfing-related illnesses experienced ( $\chi^2$  *P*-value = 0.003). (a) No surfing related illnesses (*n* = 216), (b) 1–2 surfing related illnesses (*n* = 134), (c) 3–5 surfing related illnesses (*n* = 57).

**Table 3** | Final multivariate logistic regression models of self-reported illnesses and odd ratios (with 95% CIs) for the associations with risk behaviors, use of personal PPE and other activities

	Illnesses				
	Fever	Diarrhea	Sore throat/Coughs	Ear infection/Discharges	Vomiting
	OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]
Surfing during a health advisory					
Yes	NS	1.94 <sup>a</sup> [1.03–4.64]	1.94 <sup>a</sup> [1.03–4.64]	NS	NS
Not sure	NS	1.34 [0.56–3.21]	1.32 [0.73–2.39]	NS	NS
No	Reference	Reference	Reference	Reference	Reference
Surfing during a rain event					
Often	NS	2.74 <sup>a</sup> [1.37–5.47]	1.26 <sup>a</sup> [1.01–2.05]	1.39 [1.01–2.32]	NS
Sometimes	Reference	Reference	Reference	Reference	Reference
Never	NS	<sup>b</sup> 0.35 [0.43–2.91]	<sup>b</sup> 0.21 <sup>a</sup> [0.05–0.95]	<sup>b</sup> 0.15 <sup>a</sup> [0.03–0.70]	NS
Wearing ear plugs					
Yes	3.82 <sup>a</sup> [1.91–7.67]	2.63 <sup>a</sup> [1.00–7.16]	NS	6.00 <sup>c</sup> [2.30–15.58]	NS
No	Reference	Reference	Reference	Reference	Reference
Body surfing					
Yes	2.42 <sup>a</sup> [1.24–4.74]	2.40 <sup>a</sup> [1.25–4.59]	2.32 <sup>a</sup> [1.42–3.77]	NS	2.11 <sup>a</sup> [1.01–4.40]
No	Reference	Reference	Reference	Reference	Reference
Frequency of surfing/month					
Once or twice	Reference	Reference	Reference	Reference	Reference
3–4 times	1.40 [0.47–4.17]	1.98 [0.73–5.41]	0.71 [0.36–1.36]	1.39 [0.74–2.64]	1.25 [0.39–4.06]
5–10 times	2.32 [0.84–6.36]	3.00 <sup>a</sup> [1.12–7.96]	0.95 [0.50–1.81]	1.84 [0.96–3.53]	2.28 [0.79–6.57]
More than 10 times	7.22 <sup>c</sup> [2.68–19.43]	3.17 <sup>a</sup> [1.09–9.26]	2.00 <sup>c</sup> [1.47–4.21]	2.68 <sup>a</sup> [1.23–5.87]	3.39 <sup>a</sup> [1.34–11.49]

<sup>a</sup>*p*-value < 0.05.<sup>b</sup>Category with less than 10 responses.<sup>c</sup>*p*-value < 0.001.

NS, not significant and therefore not included in the final multivariate model.

in body surfing. Among frequent surfers, those who surfed 5–10 times or more per month had three times the odds of experiencing diarrhea (OR = 3.00, 95% CI: 1.09–9.26) compared to individuals who surfed only once or twice a month. Surfing more than ten times in a month also increased the odds of experiencing diarrhea (OR = 3.17, 95% CI: 1.09–9.26) compared to surfing only once or twice in a month.

### Sore throat or cough

Individuals who surfed during a health advisory had a 2.3 increase in their odds of experiencing a sore throat/cough, as compared to individuals who had not surfed during a health advisory (OR = 2.32, 95% CI: 1.23–4.40). Surfing during a rain event also increased the odds of reporting a sore throat by 1.26 times as compared to individuals who sometimes surfed during rain events (OR = 1.26, 95% CI: 1.01–2.05). Never surfing during a rain event was protective of having a sore throat or cough (OR = 0.21, CI: 0.05–0.95). Individuals who engaged in body surfing were 2.3 times more likely to report experiencing a sore throat as compared to individuals who did not engage in body surfing (OR = 2.32, 95% CI: 1.42–3.77). The odds of reporting sore throat/cough were two times higher for individuals who surfed more than ten times in a month (OR = 2.00, 95% CI: 1.47–4.21) as compared to people who only surfed once or twice in a month.

### Ear infection or discharge

Surfing often during a rain event increased the odds of experiencing an ear infection as compared to individuals who sometimes surfed during rain events (OR = 1.39, 95% CI: 1.01–2.32). A reduction in the odds for having an ear infection or discharge was observed for individuals who never surfed during a rain event (OR = 0.15, 95% CI: 0.03–0.70). Individuals who use earplugs for surfing had six times greater odds of reporting an ear infection compared to individuals who did not wear earplugs (OR = 6.00, 95% CI: 2.30–15.58), and this was highly significant ( $p < 0.001$ ). Individuals who surfed more than ten times in a month had 2.7 times the odds of self-reporting an ear infection (OR = 2.68, 95% CI: 1.23–5.87) compared to surfing only once or twice in a month.

### Vomiting

Surfers who engaged in body surfing had twice the odds of reporting vomiting compared to individuals who do not engage in body surfing (OR = 2.11, 95% CI: 1.01–4.40). Surfing more than ten times in a month was also associated with increased odds of vomiting (OR = 3.39, 95% CI: 1.34–11.49). Multivariate results are summarized in [Table 3](#).

The range for some of the CIs were wide partially due to the small cell size of the particular health behavior. For example, never surfing during a rain event was reported only by 38 individuals (7.85%) and wearing earplugs was only reported by 33 participants (9.14%).

Even though we did not specifically examine surfing injuries or other hazards, we also asked participants about any previous surfing-related injuries or shark encounters. Overall, 290 participants (58.8%) reported having had an injury related to surfing and 89 (18.2%) reported having a shark encounter in the past (data not shown).

## DISCUSSION

We identified self-reported adverse illnesses consistent with waterborne exposure to microbial contaminants in our study of active surfers in the Pacific Northwest. These included fever, diarrhea, sore throat or cough, ear infection or discharge, and vomiting. Our findings of specific illnesses in this self-selected group of surfers are similar to prior studies that examined recreational users in ambient waters. In a California study, symptoms of GI illness, sore throat, eye and skin infections were observed in surfers, with reported symptoms increasing by 10% for each 2.5 hours of weekly water exposure as estimated by contact time in the water ([Dwight \*et al.\* 2004](#)). The results of this investigation support existing evidence of the link between exposure to coastal water impairment and adverse illnesses in marine bathers ([Cabelli \*et al.\* 1983](#); [Dewailly \*et al.\* 1986](#); [Corbett \*et al.\* 1993](#); [Kay \*et al.\* 1994](#); [Haile \*et al.\* 1999](#); [Dwight \*et al.\* 2004](#); [Turbow \*et al.\* 2008](#); [Colford \*et al.\* 2012](#)). Even though surfers are generally regarded to be young healthy adults without compromised immune systems, a surprising number of illness complaints were reported, with a low of 7% reporting vomiting, to a high of 37% reporting ear infection or

discharge. While these illness reports may seem low, surfers in this study have visited cold marine waters that are relatively low in enterococci densities (Stone *et al.* 2008). In contrast, other studies have reported higher numbers of illnesses from those who surf in warm waters which are likely to have higher levels of fecal contamination (Dewailly *et al.* 1986; Dwight *et al.* 2004; Turbow *et al.* 2008).

Our findings also demonstrated that the reporting of these signs and symptoms is associated with various risk-based behaviors. One of the primary behavioral determinants that influenced reported illnesses was the frequency of surfing events, which was significantly associated with all of the illnesses surveyed. A higher frequency of surfing is compounded by the disproportionate levels of exposure experienced by surfers compared with other water-based recreational users. The surfing population analyzed for this study reported a mean exposure of 171 mL water ingestion per surfing event (Stone *et al.* 2008). This level of incidental water ingestion is considerably higher compared to findings from Dorevitch *et al.* (2011) for rowing (3.9 mL), kayaking (3.8 mL), and canoeing (3.9 mL). It is also ten-fold higher than ingestion levels reported for adults swimming in a pool for 45 min (Dufour *et al.* 2006).

Other risk-based behaviors that influenced the reporting of illnesses included the recognition of whether an advisory was active during surfing and if that knowledge altered behavior (i.e., if the respondent continued to surf). An unexpected finding is that approximately 40% of surfers were unaware whether they had surfed during an advisory and 29% stated that they had knowingly surfed with an advisory in effect. A significant response was observed between the number who reported diarrhea and sore throat while surfing during an advisory (Figure 1). We found an increasing number of illnesses reported with increased proportions of surfers who surfed during an advisory. This is important information, as the Oregon Health Authority releases information about advisories to the media (television, newspaper, radio) and to the local authorities, posts advisory information on their website, and posts signs at the affected beaches (OHA 2013). When an advisory is issued for a particular beach, water contact is discouraged, and the website advises that people should avoid any activities during which they might swallow water, such as swimming, surfing, diving, and kayaking. It is also advised that people

should wash their hands thoroughly before eating if playing in or around water that has elevated bacteria levels.

Although there is not agreement about the extent to which advisories protect public health, given that advisories are often not synchronous with contamination events, the posting of health advisories is an attempt by state health authorities to warn the potential beach users that fecal indicator bacteria levels exceed thresholds of acceptable health risk (Turbow 2009). Given that surfers in this study either did not know that they were surfing during an advisory, or knowingly surf during a posted advisory, the postings may be serving as a passive management tool and may not deter potential bathers or surfers from entering coastal waters that may be impaired (Pendleton 2001; Turbow 2009). Beach managers, recreational organizations, coastal communities, and beach monitoring programs in the Northwest and in other coastal states can use the information obtained from this study to develop risk communication messages that reach their intended audiences, educating surfers and other bathers about the increased risk of illnesses that may result from surfing in water with elevated bacterial counts, and emphasizing the importance of practicing risk reduction behaviors. Researchers have surveyed the public's understanding and awareness of signs that alert beach users to microbial contamination and have suggested recommendations that highlight the role of other alternate communication channels to improve messaging and promote behaviors that decrease risk (Pratap *et al.* 2013).

Body surfing, in addition to board surfing, was also associated with increased reporting of adverse illnesses. Body surfing, which involves riding a wave without a surfboard or other buoyant object, was practiced by numerous respondents in our sample (33%). Body surfers had 2.4, 2.3, and 2 times the odds of reporting a fever, sore throat, and vomiting, respectively, as compared to individuals who did not body surf after adjusting for other demographic and other surfing behavior variables. Individuals who engage in body surfing tend to have a more direct contact with water and sand as the sport is often practiced close to the shore. While Heaney *et al.* (2009) did not study body surfers, their study did find a 25–50% increased risk in gastrointestinal illnesses for beachgoers who were directly exposed to sand. The close proximity and contact with sand along with more novice participants engaging in body

surfing makes it a unique exposure scenario, and additional research may be warranted.

Our study also found that surfing during rain events was associated with higher odds of developing an ear infection, sore throat, and diarrhea. In particular, there was an approximate ten-fold increase in reported diarrhea among respondents who surfed during rain events versus those that did not. In studying pre- and post-storm conditions at eight Southern California beaches, Tseng & Jiang (2012) found that surfing post-storm may exceed EPA risk guidelines up to 28% of the time and that gastrointestinal illness risks associated with surfing at post-storm conditions were significantly elevated in comparison with swimming. Increased illness has been previously reported during years in which there was greater coastal water contamination due to precipitation, as measured by mean monthly total coliform counts (Dwight *et al.* 2004). Our finding has important implications for Pacific Northwest surfers since precipitation increases the distribution of pathogenic microbes from freshwater sources into recreational marine waters, and because rain occurs through much of the year and frequently on this part of the US Pacific Coast. Furthermore, surfers frequent the beach during both dry and wet weather, and are attracted to large waves that usually accompany a wet-storm event (Bradley & Hancock 2003). The public is advised to avoid water contact for 48 hours following a heavy rain event (OHA 2013) due to shoreline contamination of water, which occurs frequently in urbanized areas and is strongly associated with patterns of rainfall and urban runoff (Dwight *et al.* 2002; Noble *et al.* 2003; see Tseng & Jiang 2012).

Another unexpected finding was the increased reporting of health effects among respondents who wore earplugs. For these individuals, the odds of reporting a fever, ear infection and diarrhea were significantly higher compared with individuals who did not wear earplugs. Some earplugs do not provide a proper fit within the ear canal, allowing water to enter into the ear and remain trapped inside, providing an ideal environment for microbial growth (Lee *et al.* 1999). It has been recognized that impermeable earplugs could act as an irritant and have also been demonstrated to predispose the ear canal to *otitis externa* (Sander 2001). Cold water surfers have been identified to be at a higher risk of suffering from

auditory exostoses compared to warm water surfers (Zoltan *et al.* 2005). Pacific Northwest surfers are constantly exposed to low water temperatures making them a vulnerable population for experiencing auditory exostoses. This is a common risk factor for *otitis externa* and other ear infections that could explain the observed association between earplug use and self-reported fever, diarrhea, and ear infections. However, given the cross-sectional design of the present study it is also possible that surfers that used earplugs were doing so because of previous or ongoing ear infections. Therefore, reverse causality cannot be ruled out. Further education on the adequate type and use of earplugs could benefit this population.

The potential for selection bias in our study exists because survey participants self-selected to visit the website (Eysenback & Wyatt 2002; Lenert & Skoczen 2002; Turbow *et al.* 2008). Our participant sample may disproportionately comprise surfers who are more interested in water pollution as it relates to health issues, and thus may not be representative of the entire group of Northwest surfers or those nationally. Conversely, web-based methods of disease investigation are regarded as a useful means of studying recreational water illness in marine waters (Turbow 2009), and also demonstrate advantages of quick turn-around time for data collection and accessibility to a large population, as compared to other survey methods (Turbow *et al.* 2008). Online surveys also offer cost-savings due to reduction in costs due to printing questionnaires and entering data for mail surveys or interviewer time for telephone surveys. These advantages must be viewed along with the limitations of inference due to the self-selected sample. Because our questionnaire was posted on the Oregon Surfrider website, we expected that the majority of our participants would be members of Surfrider Foundation, who would be frequent visitors to this site. However, we also posted announcements for the study on the Oregon Surf website, and in Oregon surf shops, which drew interest from those beyond the Surfrider membership. Only 23% of participants indicated they were members of Surfrider Foundation, so the results may be more representative of a broader population of surfers than expected.

It is also possible that an individual's perception of risk may affect the validity of self-reported illness associated with environmental exposures, especially if the participants have

knowledge about the health effects of a particular environmental exposure (Fleisher & Kay 2006). Although we cannot be sure that risk perception bias did not influence the results, the results from the multivariate model depict reasonable trends based on frequency of exposures (e.g., often or never) and identify illnesses that are consistent with waterborne exposures. There is also the potential for recall bias as participants were asked about previous illnesses experienced that were related to surfing.

Since there is no list that registers all surfers in the Pacific Northwest, it was not possible to conduct a probability sample of all surfers using a list frame. The approach taken provides a cost-effective approach to obtain views from Pacific Northwest surfers. We recognize the results are not generalizable to the population of surfers regionally, nationally, or worldwide, and that the results may be biased since they do not represent the harder-to-select population. It is also not possible to compute response rates since there are no data to determine exactly how many surfers saw the questionnaire. In addition, surfers who were interested in completing this questionnaire may have been more frequent surfers (and therefore ingest more water) than those who did not complete the questionnaire, leading to the possibility of overestimating the reported illnesses from the entire Pacific Northwest surfing population.

We also acknowledge that the questionnaire responses for illnesses are self-reported rather than documented medical 'cases'. While this is recognized as a limitation, our findings confirm what others who have used web-based illness surveys have also discovered; web-based surveys may be a useful supplement or alternative to epidemiologic investigations of surfers or other marine water recreationalists, and that these methods may ultimately contribute to an improved illness surveillance system (Turbow *et al.* 2008). We add to our optimism, however, a note of caution in recognizing that web-based surveys do not necessarily provide a representation of all Pacific Northwest surfers because not all surfers living in the Pacific Northwest have access to the web to complete surveys online. Finally, this study was cross-sectional and the temporality between exposures and self-reported illnesses cannot be assessed and the possibility for reverse causation and recall bias needs to be considered when interpreting these results. Strengths of our study include the use of previously

validated survey items in a similar population and pilot testing those items among surfers. The sample size is also relatively large given the population under study. The cross-sectional nature of our study limits our ability to evaluate cause and effect relationships but provides valuable information to inform future epidemiological studies.

---

## CONCLUSIONS

Surfing represents a higher risk activity when compared with other aquatic recreational activities such as wading or swimming, given the frequency of unanticipated head submersions, chaotic wave activity, and the potential for long exposure durations. We identified self-reported illnesses consistent with waterborne exposure to microbial contaminants in our study of active surfers in the Pacific Northwest, including fever, diarrhea, sore throat/cough, ear infection/discharge, and vomiting. Certain behaviors were significantly associated with increased reports of illnesses, including use of ear plugs, surfing during a rain event, body surfing, surfing during an active advisory, frequency of surfing, and surfing near an outfall. Showering after surfing was not significantly associated with fewer reports of adverse outcomes. A high proportion of surfers either did not know if they had surfed during an active beach advisory or continued to surf despite the advisory. These findings suggest that beach advisories are not having their intended effect of informing and deterring surfers from entering coastal waters that exceed thresholds of acceptable risk. This study highlights the need to examine the extent to which surfers and other potential marine water users are aware of health advisories and comply with recommendations, and the need to further educate this population both about behaviors that are protective of health and those that may increase risk of illnesses in contaminated waters.

---

## ACKNOWLEDGEMENTS

Support for the study was provided by Oregon Sea Grant NA-06OAR4170010. The authors would like to acknowledge Jennifer Ketterman and Rebecca Hillwig, with the Oregon Beach Monitoring Program; Catherine Neumann; Marcus Mead and Pete Stauffer with Oregon Surfrider and Kim

Rueter with Oregon Surf; and Lydia Newton of the OSU Survey Research Center.

## REFERENCES

- Arnone, R. D. & Walling, J. P. 2007 **Waterborne pathogens in urban watersheds**. *J. Water Health* **5**, 149–162.
- Benedict, R. T. & Neumann, C. M. 2004 **Evaluating Oregon's Beach sites for application to United States Environmental Protection Agency's BEACH Act criteria**. *Mar. Pollut. Bull.* **49**, 630–636.
- Boehm, A. B., Ashbolt, N. J., Colford, J. M., Dunbar, L. E., Fleming, L. E., Gold, M. A., Hansel, J. A., Hunter, P. R., Ichida, A. M., McGee, C. D., Soller, J. A. & Weisberg, S. B. 2009 **A sea change ahead for recreational water quality criteria**. *J. Water Health* **7**, 9–20.
- Bradley, G. & Hancock, C. 2003 **Increased risk of non-seasonal and body immersion recreational marine bathers contacting indicator microorganisms of sewage pollution**. *Mar. Pollut. Bull.* **46**, 791–794.
- Cabelli, V. J., Dufour, A. P., McCabe, L. J. & Levin, M. A. 1983 **A marine recreational water quality criterion consistent with indicator concepts and risk analysis**. *J. Water Pollut. Control Fed.* **55**, 1306–1314.
- Colford, J. M., Wade, T. J., Schiff, K., Wright, C., Griffith, J., Sandhu, S. K. & Weisberg, S. B. 2005 **Recreational Water Contact and Illness in Mission Bay, California**, Technical Report No. 449. Southern California Coastal Water Research Project. Los Angeles, CA. [ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/449\\_mb\\_epi.pdf](http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/449_mb_epi.pdf) (accessed 15 November 2013).
- Colford, J. M., Wade, T. J., Schiff, K. C., Wright, C. C., Griffith, J. F., Sundhu, S. K., Burns, S., Sobsey, M., Lovelace, G. & Weisberg, S. B. 2007 **Water quality indicators and risk of illness at beaches with nonpoint sources of fecal contamination**. *Epidemiology* **18**, 27–35.
- Colford, J. M., Schiff, K. C., Griffith, J. F., Yau, V., Arnold, B. F., Wright, C. C., Gruber, J. S., Wade, T. J., Burns, S., Hayes, J., McGee, C., Gold, M., Cao, Y., Noble, R. T., Haugland, R. & Weisberg, S. B. 2012 **Using rapid indicators for *Enterococcus* to assess the risk of illness after exposure to urban runoff contaminated marine water**. *Water Res.* **46**, 2176–2186.
- Corbett, S. J., Rubin, G. L., Curry, G. K., Kleinbaum, D. G. & Sydney Beach Users Advisory Group. 1993 **The health effects of swimming at Sydney beaches**. *Am. J. Public Health* **83**, 1701–1706.
- Dewailly, E., Poirier, C. & Meyer, F. M. 1986 **Health hazards associated with windsurfing on polluted water**. *Am. J. Public Health* **76**, 690–691.
- Dorevitch, S., Panthi, S., Huang, Y., Li, H., Michalek, A. M., Pratap, P., Wroblewski, M., Liu, L., Scheff, P. A. & Li, A. 2011 **Water ingestion during water recreation**. *Water Res.* **45**, 2020–2028.
- Dufour, A. P., Evans, O., Behymer, T. D. & Cantu, R. 2006 **Water ingestion during swimming activities in a pool: a pilot study**. *J. Water Health* **4**, 425–430.
- Dwight, R., Semenza, J., Baker, D. & Olson, B. 2002 **Association of urban runoff with coastal water quality in Orange County, California**. *Water Environ. Res.* **74**, 82–90.
- Dwight, R. H., Baker, D. B., Semenza, J. C. & Olson, B. H. 2004 **Health effects associated with recreational coastal water use: urban versus rural California**. *Am. J. Public Health* **94**, 565–567.
- Eysenback, G. & Wyatt, J. 2002 **Using the internet for surveys and health research**. *J. Med. Internet Res.* **4**, pe13. doi:10.2196/jmir.4.2.e13.
- Fleisher, J. M. & Kay, D. 2006 **Risk perception bias, self-reporting of illness, and the validity of reported results in an epidemiologic study of recreational water associated illnesses**. *Mar. Pollut. Bull.* **52**, 264–268.
- Haile, R., Witte, J., Gold, M. N., Cressey, R., McGee, C., Millikan, R., Glasser, A., Harawa, N., Ervin, C., Harmon, P., Harper, J., Dermand, J., Alamillo, J., Barrett, K., Nides, M. & Wang, G. 1999 **The health effects of swimming in ocean water contaminated by storm drain runoff**. *Epidemiology* **10**, 355–363.
- Heaney, C. D., Sams, E., Wing, S., Marshall, S., Brenner, K., Dufour, A. P. & Wade, T. J. 2009 **Contact with beach sand among beachgoers and risk of illness**. *Am. J. Epidemiol.* **170**, 164–172.
- Kay, D., Fleisher, J., Salomon, R., Jones, F., Wyer, M., Godfree, A., Zelenauch-Jacquotte, Z. & Shore, R. 1994 **Predicting likelihood of gastroenteritis from seabathing: results from randomized exposure**. *Lancet* **344**, 905–909.
- Lee, D., Youk, A. & Goldstein, N. A. 1999 **A meta-analysis of swimming and water precautions**. *Laryngoscope* **109**, 536–540.
- Lenert, L. & Skoczen, S. 2002 **The internet as a research tool: Worth the price of admission?** *Ann. Behav. Med.* **24**, 251–256.
- Myers, R. H. 1990 *Classical and Modern Regression with Applications*. Vol. 2. Duxbury Press, Belmont, CA.
- Nathanson, A., Haynes, P. & Galanis, D. 2002 **Surfing injuries**. *Am. J. Emerg. Med.* **20**, 155–160.
- National Resources Defense Council 2013 **Testing the Waters 2013: Oregon**. <http://www.nrdc.org/water/oceans/ttw/or.asp> (accessed 15 October 2013).
- Neumann, C. M., Harding, A. K. & Sherman, J. M. 2006 **Oregon Beach monitoring program: bacterial exceedances in marine and freshwater creeks/outfall samples, October 2002–April 2005**. *Mar. Pollut. Bull.* **52**, 1270–1277.
- Noble, R., Weisberg, S., Leecaster, M., McGee, C., Dorsey, J., Vainik, P. & Orozco-Borbon, V. 2003 **Storm effects on regional beach water quality along the southern California shoreline**. *J. Water Health* **1**, 23–31.
- Oregon Health Authority 2013 **Beach Water Quality Program**. <http://public.health.oregon.gov/HealthyEnvironments/Recreation/BeachWaterQuality/Pages/beaches.aspx> (accessed 15 October 2013).

- Pendleton, L. 2001 [Managing beach amenities to reduce exposure to coastal hazards: storm water pollution](#). *Coast. Manage.* **29**, 239–252.
- Perez Guzzi, J., Folabella, A., Miliwebsky, E., Rivas, M., Fernandez Pascua, C., Gomez, D., Zomora, A., Zotta, C. & Cordoba, M. 2000 Isolation of *Escherichia coli* 0157:H7 in combined-sewer overflows with fecal bacterial contamination in Mar del Plata. *Argentina de Microbiol.* **32**, 161.
- Pratap, P., Redman, S., Fagen, M. & Dorevitch, S. 2013 [Improving water quality communications at beaches: input from stakeholders](#). *J. Water Health* **11**, 647–658.
- Prüss, A. 1998 [Review of epidemiological studies on health effects from exposure to recreational water](#). *Int. J. Epidemiol.* **27**, 1–9.
- Sander, R. 2001 Otitis externa: a practical guide to treatment and prevention. *Am. Fam. Physician* **63**, 927–942.
- Schijven, J. & de Roda Husman, M. 2006 [A survey of diving behavior and accidental water ingestion among Dutch occupational and sport divers to assess the risk of infection with waterborne pathogenic microorganisms](#). *Environ. Health Persp.* **114**, 712–717.
- Stone, D. L., Harding, A. K., Hope, B. K. & Slaughter-Mason, S. 2008 [Exposure assessment and risk of gastrointestinal illness among surfers](#). *J. Toxicol. Environ. Health, Part A.* **71**, 1603–1615.
- Tseng, L. Y. & Jiang, S. C. 2012 [Comparison of recreational health risks associated with surfing and swimming in dry weather and post-storm conditions at Southern California beaches using quantitative microbial risk assessment \(QMRA\)](#). *Mar. Pollut. Bull.* **64**, 912–918.
- Turbow, D. 2009 [Addressing disease surveillance needs for marine recreational bathers](#). *J. Water Health* **7**, 45–54.
- Turbow, D. J., Osgood, N. D. & Jiang, S. C. 2003 [Evaluation of recreational health risk in coastal waters based on enterococcus densities and bathing patterns](#). *Environ. Health Persp.* **111**, 598–603.
- Turbow, D. J., Kent, E. E. & Jiang, S. C. 2008 [Web-based investigation of water associated illness in marine bathers](#). *Environ. Res.* **106**, 101–109.
- United States Environmental Protection Agency (USEPA). 1986 [Ambient Water Quality Criteria for Bacteria-1986](#). EPA440/5-84-002. Office of Water, US Environmental Protection Agency, Washington, DC.
- United States Environmental Protection Agency (USEPA). 2002 [Implementation Guidance for Ambient Water Quality Criteria for Bacteria](#). EPA-823-B-02-003. US Environmental Protection Agency, Washington, DC.
- United States Environmental Protection Agency (USEPA). 2004 [Water quality standards for coastal and Great Lakes recreation waters: final rule](#). *Fed. Regist.* **69** (220), 67218–67243.
- Wade, T. J., Pai, N., Eisenberg, J. N. S. & Colford, J. M. 2003 [Do US EPA water quality guidelines for recreational waters prevent gastrointestinal illness? A systematic review and meta-analysis](#). *Environ. Health Persp.* **111**, 1102–1109.
- Zoltan, T. B., Taylor, K. S. & Achar, S. A. 2005 [Health issues for surfers](#). *Am. Fam. Physician* **71**, 2313–2317.

First received 25 November 2013; accepted in revised form 31 May 2014. Available online 24 June 2014