Coastal Management, 37:529–549, 2009

ISSN: 0892-0753 print / 1521-0421 online
DOI: 10.1080/08920750903044865

Surfer and Beachgoer Responsiveness to Coastal Water Quality Warnings

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Fecal contamination of coastal waters has led local public health agencies to issue tens of thousands of beach advisories annually and to advise against ocean swimming and surfing for 72 hours following a rain. The responsiveness of recreationists to beach advisories and the "72 hour rule" is estimated by merging four years of multi-daily surfer and beachgoer counts at one beach in Southern California with hourly data on beach advisories, recent precipitation, meteorological conditions, and the UCSB academic calendar. Both surfing and beach-going decreased significantly following rainfall in response to the 72 hour rule, showing that recreationists are willing to engage in health risk-reducing avoiding behavior. However, neither surfing nor beach-going decreased significantly during beach advisories. Surfers were significantly more responsive to beach advisories during dry periods than during wet periods, consistent with the hypothesis that recreationists are most likely to respond to a risk warning that they believe provides accurate and additional health risk information beyond what they can observe personally. Additional studies of beach advisories elsewhere could clarify whether responsiveness to beach advisories varies by recreationist demographic, recreational activity, frequency of advisories, or frequency of repeat visitation. Increasing the accuracy and additional information provided by beach advisories, as proposed by numerous authors, could lead to increased responsiveness.

Keywords avoiding behavior, beach advisories, coastal water quality, risk advisories

Introduction

Risk advisories are a growing public health policy response to the health risks associated with the pollution of recreational environments. In the case of coastal recreation, public health agencies post beach advisories when tests of periodically collected water samples indicate that bacterial concentrations exceed safe limits. The development of heuristics, or rules of thumb, regarding the times or locations of recreation with the greatest expected

The author is grateful to Jennifer Stroh of the Snowy Plover Docent Program and Willie Brummett of the Santa Barbara County Water Quality Monitoring Program for providing data, to Glenn Sharp and Todd Strand for research assistance, and to Chris Costello, Frank Davis, Bob Deacon, Patricia Holden, Matt Kotchen, Linwood Pendleton, seminar participants at the University of California, Santa Barbara, members of the Isla Vista and Santa Barbara chapters of Surfrider Foundation, and three anonymous referees for helpful comments. Funding was provided by NSF grant 0114437 and the University of California Santa Barbara Associated Students Coastal Fund.
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health risk form a second public health policy response polluted environments. In the case of coastal recreation, public health agencies discourage ocean swimming or surfing for 72 hours following a rain (the "72 hour rule"). The effectiveness of risk advisories and heuristics in minimizing health damages from pollution hinges on the premise that recreationists will respond to these sources of additional information on health risks by engaging in avoiding behavior. This article analyzes the responsiveness of surfers and beachgoers to beach advisories and the 72 hour rule over a four-year period at Sands Beach in Santa Barbara County, California.

This article addresses the question, "How responsive are surfers and beachgoers to beach advisories and the 72 hour rule?" by exploiting a unique data set of multi-daily surfer and beachgoer counts over four years at a single, infrequently polluted beach. Surfer and beachgoer counts are merged with hourly data on meteorological conditions, time-variant recreational demand, recent rainfall, and the presence or absence of a beach advisory. This article extends the environmental risk advisory responsiveness literature by producing the first revealed preference analysis of public responsiveness to water quality risk advisories and among the first longitudinal revealed preference analyses of responsiveness to any public health advisory.

Increases in recent rainfall were correlated with decreases in surfing and beach visitation at Sands Beach, consistent with recreationists responding to the 72 hour rule. So, surfers and beachgoers appear willing to engage in health risk-reducing avoiding behavior. However, beach advisories were not correlated with decreases in surfing and beach visitation at Sands Beach, perhaps because recreationists were not convinced of the accuracy or additional information on health risk provided by beach advisories. Increasing the accuracy and additional information provided by advisories, as proposed by numerous authors, could lead to increased responsiveness.

Background

Fecal contamination of coastal water occurs as a result of sewage discharge or surface runoff. Most sanitation facilities in the United States have upgraded to comply with federal discharge laws, turning the attention of planners and policymakers to untreated surface runoff (Dwight et al., 2005). Fecally contaminated coastal water has been linked to increased risk of gastrointestinal illness, respiratory disease, and eye and ear infections in swimmers (Kay et al., 1994; Fleisher, 1998; Pruss, 1998; Haile et al., 1999) and surfers (Dwight et al., 2004). Illnesses from recreation in contaminated coastal waters have been estimated to cost \$3.3 million annually in public health burden at two Southern California beaches (Dwight et al., 2005), \$21–51 million annually in financial losses at 28 Southern California beaches (Given et al., 2006), and \$700 million annually in direct financial losses globally (Shuval, 2003).

Legislation has been enacted at both the federal and state level to monitor pollution of coastal waters and to inform the public of associated health risk. The Beaches Environmental Assessment and Coastal Health (BEACH) Act of 2000 authorizes the EPA to provide grants to states to monitor public beaches for compliance with federal health standards, and to notify the public when these standards are exceeded. In California, AB 411 requires counties to perform weekly April–October monitoring of all beaches with annual visitation above 50,000 or within 150 meters of a river mouth. (California State DHS, 1997)

Health standards at both the federal and state level use the EPA's 1986 criteria for testing recreational waters, based on monitoring of concentrations of three indicator organisms—enterococcus, fecal coliform, and total coliform (Cabelli et al., 1982). Beach advisory and closure policies vary by state (Dorfman & Stoner, 2007). In the state of California, a beach advisory is issued when the concentration of any indicator organism is found to exceed the EPA-determined threshold, while a beach closure is issued in response to a sewage spill or repeated incidences of exceedances from an unknown source (CA SWRCB, 2009). In 2006, U.S. ocean, bay, Great Lakes, and freshwater beaches had 25,643 beach-days of temporary closings and advisories, and 4,152 beach-days of extended or permanent closings and advisories (Dorfman & Stoner, 2007).

The current monitoring practice has several weaknesses. Single collected samples are subject to sampling error, as pathogen concentrations in samples have been found to be highly variable across space and time (Boehm et al., 2002). Long incubation periods and infrequent sampling create several days of lag between the time of a pollution event and the time an advisory is issued. Kim and Grant (2004) found that beach advisories at Huntington Beach mis-notified the public by being incorrect as often as 40% of the time at one posting station. Advisories would have had to have been updated every 40 minutes to have significantly reduced the probability of mis-notification.

These weaknesses have led to calls to develop quicker or more accurate tests (Wade et al., 2003). Wade et al. (2006) showed that rapidly measured indicator methods, which can measure indicator organism concentrations in less than two hours, were predictive of illness risk at two Great Lakes beaches. Because indicator organism concentrations have been found to correlate with meteorological factors such as season, tide, tidal range, current, and recent rainfall, some research has proposed that beach advisories be based on predictive models rather than tests (Kim & Grant, 2004; Hou et al., 2006), or as probabilistic rather than binary warnings (Kim & Grant, 2004). Some Great Lakes beaches do issue beach advisories based on predictive models (Hou et al., 2006). Hou et al. (2006) showed that beach advisories that combine a predictive model with a recently collected sample are more accurate than advisories based on a collected sample alone. Frick et al. (2008) demonstrate the usefulness of site-specific predictive models that are based on limited time period data sets and refitted as new data become available.

Previous studies of the public health benefits of beach advisories have estimated that beach advisories are so inaccurate as to be welfare decreasing, with the benefits from reduced illnesses during high risk periods were outweighed by the losses from decreased recreation during low risk periods (Rabinovici et al., 2004; Hou et al., 2006; Pendleton, 2008). These studies have assumed that during an advisory swimming is reduced by 90% (Hou et al., 2006), or drops to zero (Rabinovici et al., 2004; Pendleton, 2008). However, as noted in Hou et al. (2006), "there is presently no published information about the ... fraction of swimmers that would still choose to enter the water ... when there was an advisory in place." In this study, the first empirical estimates of recreational responsiveness to beach advisories is presented.

In light of the literature on consumer and recreationist responsiveness to risk warnings, it is probably not reasonable to expect high responsiveness on the part of surfers or beachgoers to beach advisories. A study by Lew and Larson (2005) found that beach advisories did not significantly affect beachgoers' site choice. In other contexts, responsiveness on the part of consumers or recreationists to health risk advisories has been found to be modest (e.g., Smith et al., 1995; MacDonald & Boyle, 1997; Jakus et al., 1997, 1998; Mathios, 2000; Shimshack et al., 2007; Neidell, 2006), or non-existent (e.g. May & Burger, 1996; Fenn et al., 2001; Sloan et al., 2002). An exception is Brown and Schrader (1990). Much of this evidence has come from surveys (Smith et al., 1995; May & Burger 1996; MacDonald & Boyle, 1997; Jakus et al., 1997, 1998) rather than revealed preference studies. Most revealed preference investigations have relied on before-and-after approaches (Shimshack et al., 2007; Speir, 2008) or looked at long-term time trends (Brown & Schrader, 1990; Mathios, 2000; Fenn et al., 2001; Sloan et al., 2002). At the time of this study, the author is aware of only one revealed preference investigation of risk warnings and avoiding behavior with multiple variations in risk information over the course of a longitudinal analysis (Neidell, 2006). This research extends the risk advisory responsiveness literature by producing the first revealed preference analysis of public responsiveness to water quality warnings and among the first longitudinal revealed preference analyses of responsiveness to any public health advisory.

Study Site and Data

The empirical goal of this research was to determine the response of surfers and beachgoers to two types of risk warnings—beach advisories and recent rainfall. To achieve this goal, changes in the number of recreationists that occur in response to risk warnings must be distinguished from changes in the number of recreationists that occur due to time-variant wave quality and recreational demand. This section describes recreation at Sands Beach, and the water quality, time, and meteorological variables which influence the number of recreationists at any hour.

Sands Beach is located in the University of California, Santa Barbara's Coal Oil Point Reserve. It is located 2.5 km west of the UCSB campus, 1 km west of the residential neighborhood of Isla Vista (pop. 18,000), and 1 km south-east of the Goleta neighborhood of Ellwood. Sands Beach is home to a colony of endangered Western Snowy Plovers. The volunteer docents of the Snowy Plover Docent Program keep watch at the plover reserve in two hour shifts, sun-up to sun-down, rain-or-shine, every day of the year. At the beginning of each shift, the docents record the number of individuals in the water and on the beach. These counts of surfers and beachgoers at Sands Beach, recorded up to 11 times daily from January 19, 2004 to February 29, 2008, form the dependent variables for this research. Individuals in the water are referred to throughout this article as surfers, although there are occasionally a small number of waders and swimmers at Sands Beach. Individuals on the beach are referred to throughout this article as beachgoers, although this population includes individuals who have just surfed or who will soon do so.

Although not required under California's AB 411, the Santa Barbara County Department of Environmental Health monitored water quality at Sands Beach every Monday morning beginning August 2003. Samples of ocean water were collected every Monday morning at Sands Beach at the same location in knee-deep water. Following EPA guidelines (Cabelli et al., 1982), these samples were tested for three indicator organisms (enterococcus, fecal coliform, total coliform) on Monday evening, with lab results received by Tuesday evening. If any indicator organism was found to exceed the EPA-determined health standard, a beach advisory was issued Wednesday morning. A bilingual sign was prominently displayed near the surf break at Sands Beach stating, "WARNING! CONTACT WITH THIS WATER MAY CAUSE ILLNESS; BACTERIA LEVELS EXCEED HEALTH STANDARDS." Advisories were also made public online and through the local newspaper. On Wednesday mornings when a beach advisory had been issued, a resample was taken. If the resample was not in exceedance, the beach advisory was removed on Friday morning. If the resample was in exceedance, the beach advisory remained in place until the following Wednesday. Data on the presence or absence of beach advisories were provided by the Santa Barbara Environmental Health Services Ocean Monitoring Program. The exact time at which the beach advisory sign was put in place was not recorded, but was always around 10 am

(Willie Brummett, personal communication). The present analysis assumes that beach advisories were always placed and removed at 10 am. A total of seven beach advisories, and no beach closures, were issued at Sands Beach over the study period from January 19, 2004 to February 29, 2008. This represents 28 beach advisory days out of 1,503 days in the sample (1.9%), or 111 out of 6,509 observations (1.7%). Sands Beach has relatively few beach advisories for Santa Barbara County, having the fourth fewest beach advisory days over the study period of all 21 monitored Santa Barbara County beaches (Santa Barbara Environmental Health Services Ocean Monitoring Program, unpublished data).

Most Southern California counties formally advise against swimming or surfing within 72 hours after heavy rainfall (Dorfman & Stoner, 2007), and there is evidence that local surfers are aware of this advice. A survey of 132 surfers at five Santa Barbara County and Ventura County surf beaches found that when asked, "after it rains in Southern California, how long SHOULD you wait before entering the ocean," 68% of surfers responded "72 hours or more," whereas only 7% responded "should not wait" or "don't know." Furthermore, 67% reported that the amount of time a rainfall event lasts impacts their surfing decision (Rumbley, 2007). However, responsiveness to recent rainfall may not extend to responsiveness to posted advisories. The same study found that while 84% reported having a friend who had experienced an illness attributable to the ocean, only 25% reported concern about contracting an illness from surfing when bacteria levels are unsafe, and just 15% reported always or almost always checking bacteria levels before surfing (Rumbley, 2007).

Beachgoer and surfer responsiveness to risk warnings are examined. Although health risk warnings apply only to recreationists who are exposed to coastal water, beachgoers may still be expected to respond to advisories, insofar as beach going and surfing or swimming represent complementary activities. Some recreationists may participate in both beach going and surfing; some portion of beach going at Sands Beach is likely attributable to surf watching. In addition, estimates of beachgoer responsiveness to exogenous conditions can be used to judge whether the econometric models employed produce results which accord with expected recreational behavior.

Sands Beach is one of the three most popular surf breaks within biking distance of the UCSB student population. Recreational demand varies cyclically based on the time of day, the day of the week, and the UCSB academic calendar. Data on UCSB academic holidays, vacations, and final exams were obtained from the UCSB Office of the Registrar's Approved Academic Calendars. Week of the year dummy variables were included to account for seasonal variation in daylight hours and recreational demand. Recreational demand also varies based on local weather conditions. Hourly data on air temperature, cloud cover, wind speed, and precipitation were obtained from NOAA's weather station at the Santa Barbara airport (34.4278° N, 119.8394° W), located 4 km northeast of Sands Beach. Where surfer and beachgoer counts were recorded on the half hour rather than on the hour, meteorological data were linearly interpolated.

The quality of surfable waves at Sands Beach varies seasonally and by time of day. Sands Beach has the most consistently surfable waves in the greater Santa Barbara area, due to the west-facing orientation of its coastline. During the winter months, surfable waves are generally present throughout the day at Sands Beach, generated by long distance ground swell originating in the west and northwest Pacific Ocean. During the summer months, surfable waves are restricted to the late afternoon and evening. Summer waves at Sands Beach are typically generated by localized wind swell in the Santa Barbara Channel; long distance ground swell from the southwest Pacific Ocean is blocked by the Channel Islands and does not reach Sands Beach. Local storm events are infrequent and typically do not generate quality surf waves at Sands Beach.

The quality of surfable waves also depends on ocean conditions. Hourly data on wave height, wave period, and sea surface temperature were obtained from NOAA Buoy 46053 (34.2361° N, 119.8500° W), located 19 km SE of Sands Beach (34.4075° N, 119.8760° W). Hourly tide height data were taken from NOAA station 9411340 in Santa Barbara (34.4083° N, 119.6861° W), located 18 km east of Sands Beach. Predicted tide, which was available for all hours, was used in place of observed tide, which was only available for 50.3% of the hours during the sample period. The correlation coefficient, r, between hourly predicted and observed tide over the sample period was 0.992 ($n = 22061$; $p < .000001$). Data on water clarity was available only from September 14, 2005 to September 14, 2007, from the Santa Barbara Coastal Long Term Ecological Research Project at Stearns Wharf in Santa Barbara (34.4080° N, 119.6850° W), 18 km east of Sands Beach.

The timing of recorded counts, while subject to the schedule of volunteers, does not appear to introduce sample bias. The sampled hours (n = 6,509) appeared to be representative of all daylight hours between nautical twilight and nautical twilight, as reported by the U.S. Naval Observatory (Table 1), over the four-year sample period (n = 21,223). Early morning (<7 am) and evening (>5 pm) hours were slightly under-represented in the sample. Sample hours had slightly lower air temperature and significantly lower rainfall than overall daylight hours. Sampled hours were included in the analysis only when all meteorological variables were available for that hour. The included hours (n = 5,980) appeared to be representative of sampled hours (Table 1).

Estimation Strategy

Aggregate count data is used to determine the responsiveness of surfer and beachgoer numbers to risk warnings and to exogenous time and meteorological variables. Ordinary least squares (OLS) regressions are not well suited for count data with a large number of zero observations (28.6% of surf observations and 19.8% of beachgoer observations, in this sample). Instead, the Poisson quasi-maximum likelihood estimator (QMLE), the standard model for count data, is employed. The count data in this study is overdispersed (variance of counts exceeds mean; Table 1), which can result in standard errors that are too low (Haab & McConnell, 2002). Still, the Poisson QMLE is superior to the negative binomial for estimating conditional means due to its robustness (Wooldridge, 2002). Robust standard errors are employed to account for heteroskedasticity, due to potentially imprecise counts by volunteers during the busiest times.

Although counts of surfers and beachgoers are not independent (correlation coefficient $r = 0.41$; $n = 6467$; $p < .000001$), models for surfers and beachgoers are estimated separately because explanatory variables affect the two counts differently. The robust Poisson model for the number of surfers at Sands Beach at time t, S_t, is:

$$\ln S_t = \beta_0 + M_t'\beta_1 + C_t'\beta_2 + \beta_3 A_t + \beta_4 R_t \tag{1}$$

where M_t represents a vector of hourly meteorological conditions at time t, C_t represents a vector of calendar variables at time t, A_t represents the presence or absence of a beach advisory at time t, and R_t represents the millimeters of rainfall in the 72 hours preceding time t. The number of beachgoers at Sands Beach at time t, B_t, is modeled similarly:

$$\ln B_t = \beta_0 + M_t'\beta_1 + C_t'\beta_2 + \beta_3 A_t + \beta_4 R_t \tag{2}$$

Regression results from the Poisson model with robust standard errors are shown in Table 2. Coefficients on the time of day dummy variables are relative to the hours 11 am–1 pm, which

Table 1
Summary statistics

	Overall daytime (Nautical twilight-nautical twilight, Jan. 19, 2004–Feb.29, 2008)		Sampled		Included	
Number	21,223		6,509		5,980	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Surfers			7.5	10.7	7.5	10.7
Beachgoers			7.9	12.3	7.9	12.3
	Fraction of total		Fraction of total		Fraction of total	
Time of day						
Pre-7 am	0.19		0.10		0.11	
7–9 am	0.14		0.17		0.17	
9:01–11 am	0.14		0.17		0.17	
11:01 am–1 pm	0.14		0.17		0.17	
1:01–3 pm	0.14		0.17		0.17	
3:01–5 pm	0.14		0.14		0.14	
Post-5 pm	0.10		0.08		0.08	
Day of week						
Monday	0.14		0.13		0.13	
Tuesday	0.14		0.16		0.15	
Wednesday	0.14		0.14		0.13	
Thursday	0.14		0.15		0.15	
Friday	0.14		0.13		0.13	
Saturday	0.14		0.14		0.14	
Sunday	0.14		0.15		0.15	
UCSB calendar						
Winter break	0.06		0.04		0.04	
Winter quarter	0.17		0.17		0.17	
Spring break	0.02		0.02		0.02	
Spring quarter	0.18		0.23		0.24	
Summer	0.31		0.33		0.32	
Fall quarter	0.19		0.15		0.15	
Other holiday	0.02		0.02		0.02	
Finals week	0.05		0.05		0.05	
Meteorological variables	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Wave height (m)	1.38	0.63	1.37	0.62	1.38	0.62
Wave period (sec)	10.27	3.36	10.14	3.25	10.19	3.26
Tide (m)	0.83	0.52	0.83	0.50	0.82	0.50
Wind speed (m/s)	1.64	1.72	1.49	1.68	1.54	1.67
Sea surface temperature (C)	14.90	2.17	14.80	2.19	14.74	2.17
Air temperature (C)	13.01	4.73	12.23	4.62	12.73	4.65
Cloud cover (%)	35.6	45.1	34.2	48.3	36.1	45.7
Precipitation (mm/hr)	0.033	0.394	0.025	0.297	0.027	0.306
Risk variables						
Precip. in last 72 hours (mm)	2.65	9.85	2.30	9.31	2.39	9.48
Advisory in place (0/1)	0.018		0.017		0.018	

Table 2
Surfer and beachgoer responsiveness to risk warnings

	Poisson (Robust)					
Dependent variable	Surfers		Beachgoers		Surfers	
Number of observations	5980		5986		5980	
	Coefficient	z-statistic	Coefficient	z-statistic	Coefficient	z-statistic
Constant	−1.57***	(−4.15)	1.40***	(4.34)	−1.24***	(−3.29)
Time of day						
Pre-7 am	−1.62***	(−15.15)	−1.90***	(−20.30)	−1.61***	(−15.07)
7–9 am	−0.85***	(−15.23)	−1.28***	(−23.51)	−0.84***	(−15.19)
9–11 am	−0.27***	(−5.73)	−0.67***	(−11.58)	−0.26***	(−5.63)
11 am–1 pm	(dropped)		(dropped)		(dropped)	
1–3 pm	0.13***	(2.98)	0.61***	(13.35)	0.13***	(3.00)
3–5 pm	0.26***	(5.22)	0.45***	(9.04)	0.27***	(5.30)
Post-5 pm	0.55***	(7.80)	0.039	(0.57)	0.55***	(7.85)
Day of week						
Monday	−0.19***	(−3.31)	−0.44***	(−6.93)	−0.20***	(−3.38)
Tuesday	−0.31***	(−5.27)	−0.56***	(−9.03)	−0.31***	(−5.40)
Wednesday	−0.049	(−0.85)	−0.39***	(−6.41)	−0.051	(−0.88)
Thursday	−0.073	(−1.35)	−0.37***	(−6.02)	−0.075	(−1.38)
Friday	(dropped)		(dropped)		(dropped)	
Saturday	0.18***	(3.35)	0.43***	(7.33)	0.18***	(3.37)
Sunday	0.08	(1.56)	0.37***	(6.52)	0.083	(1.53)
Week of year dummy variables	yes		yes		yes	
UCSB calendar						
Winter break	0.36**	(2.03)	−0.35	(−1.14)	0.34*	(1.84)
Spring break	−0.46**	(−2.27)	−0.51**	(−2.19)	−0.47**	(−2.33)

Summer	−0.087	(0.57)	0.039	(0.26)	0.072	(0.47)
Other holiday	0.27**	(2.25)	0.77***	(5.96)	0.26**	(2.19)
Finals week	0.21*	(1.89)	0.11	(0.92)	0.18	(1.62)
Time trend (days)	-3.1×10^{-4}***	(−6.90)	-2.4×10^{-4}***	(−5.16)	-3.1×10^{-4}***	(−6.75)
Meteorological variables						
Wave height (m)	2.82***	(12.58)	0.71***	(3.28)	2.78***	(12.49)
Wave height squared (m^2)	−0.84***	(−8.16)	−0.26***	(−2.74)	−0.82***	(−8.06)
Wave height cubed (m^3)	0.069***	(5.11)	0.028**	(2.25)	0.068***	(5.07)
Wave period (sec)	0.043***	(6.69)	0.011*	(1.69)	0.043***	(6.70)
Tide (m)	0.46***	(14.15)	-3.1×10^{-4}	(−0.01)	0.46***	(14.03)
Wind speed (km/h)	−0.088***	(−7.41)	−0.084***	(−7.13)	−0.087***	(−7.31)
Water temperature (C)	−0.0030	(−0.24)	−0.0018	(−0.14)	−0.0028	(−0.22)
Air temperature (C)	0.037***	(6.36)	0.046***	(7.32)	0.037***	(6.21)
Cloud cover (/100%)	−0.15***	(−4.12)	−0.62***	(−15.00)	−0.15***	(−4.13)
Current precipitation (mm/hr)	−0.21**	(−2.17)	−0.099	(−1.26)	−0.20**	(−2.11)
Risk variables						
Precipitation in last 72 hours (mm)	−0.0061**	(−2.50)	−0.015***	(−5.57)	−0.0064**	(−2.59)
Advisory in place (0/1)	0.27**	(2.25)	−0.076	(−0.60)		
Advisory 1 (June 3–5, 2004)					−0.30	(−1.19)
Advisory 2 (Dec. 29, 2004–Jan. 8, 2005)					−0.20	(−0.70)
Advisory 3 (Jan. 12–20, 2005)					0.75***	(4.40)
Advisory 4 (Aug. 2–4, 2006)					0.13	(0.27)
Advisory 5 (Apr. 11–13, 2007)					−1.87**	(−2.51)
Advisory 6 (Jan. 9–11, 2008)					0.66***	(3.09)
Advisory 7 (Jan. 30–Feb. 1, 2008)					−0.18	(−0.26)
Advisories at other surfing beaches						
Advisories at other swimming beaches						
Pseudo-R^2	0.34		0.39		0.34	

(Continued on next page)

Table 2
Surfer and beachgoer responsiveness to risk warnings *(Continued)*

	Poisson (Robust)					
Dependent variable	Beachgoers		Surfers		Beachgoers	
Number of observations	5986		5980		5986	
	Coefficient	z-statistic	Coefficient	z-statistic	Coefficient	z-statistic
Constant	1.43***	(4.43)	−1.26***	(−3.39)	1.39***	(4.33)
Time of day						
pre-7 am	−1.89***	(−20.26)	−1.60***	(−15.05)	−1.88***	(−20.19)
7–9 am	−1.28***	(−23.45)	−0.84***	(−15.12)	−1.27***	(−23.49)
9–11 am	−0.67***	(−11.54)	−0.26***	(−5.63)	−0.67***	(−11.51)
11 am–1 pm	(dropped)		(dropped)		(dropped)	
1–3 pm	0.61***	(13.38)	0.13***	(2.99)	0.61***	(13.43)
3–5 pm	0.45***	(9.10)	0.27***	(5.28)	0.45***	(9.10)
post 5 pm	0.042	(0.63)	0.55***	(7.86)	0.045	(0.68)
Day of week						
Monday	−0.45***	(−7.00)	−0.19***	(−3.26)	−0.45***	(−6.98)
Tuesday	−0.57***	(−9.10)	−0.31***	(−5.34)	−0.57***	(−9.11)
Wednesday	−0.39***	(−6.45)	−0.06	(−1.05)	−0.41***	(−6.71)
Thursday	−0.37***	(−6.09)	−0.09*	(−1.65)	0.43***	(7.33)
Friday	(dropped)		(dropped)		(dropped)	
Saturday	0.43***	(7.31)	0.18***	(3.35)	0.43***	(7.33)
Sunday	0.36***	(6.47)	0.08	(1.53)	0.36***	(6.48)
Week of year dummy variables	Yes		Yes		Yes	
UCSB calendar						
Winter break	−0.37	(−1.36)	0.39**	(2.15)	−0.28	(−0.97)
Spring break	−0.52**	(−2.24)	−0.43**	(−2.15)	−0.47**	(−2.00)
Summer	0.021	(0.14)	0.09	(0.58)	0.037	(0.25)

Other holiday	0.76***	(5.94)	0.25**	(2.16)	0.76***	(6.02)
Finals week	0.083	(0.68)	0.22**	(2.04)	0.11	(0.91)
Time trend (days)	-2.4×10^{-4}***	(−5.21)	-3.1×10^{-4}***	(−6.75)	-2.2×10^{-4}***	(−4.93)
Meteorological variables						
Wave height (m)	0.70***	(3.25)	2.78***	(12.47)	0.69***	(3.24)
Wave height squared (m^2)	−0.26***	(−2.69)	−0.83***	(−8.06)	−0.25***	(−2.64)
Wave height cubed (m^3)	0.027**	(2.21)	0.068***	(5.05)	0.027**	(2.15)
Wave period (sec)	0.011*	(1.66)	0.044***	(6.88)	0.011*	(1.68)
Tide (m)	−0.0039	(−0.10)	0.46***	(14.11)	5.2×10^{-4}	(0.01)
Wind speed (km/h)	−0.084***	(−7.08)	−0.086***	(−7.25)	−0.081***	(−6.92)
Water temperature (C)	−0.0011	(−0.09)	−0.0061	(−0.48)	−0.0036	(−0.29)
Air temperature (C)	0.045***	(7.12)	0.036***	(6.10)	0.044***	(7.17)
Cloud cover (/100%)	−0.62***	(−14.92)	−0.14***	(−3.98)	−0.62***	(−15.15)
Current precipitation (mm/hr)	−0.093	(−1.18)	−0.21**	(−2.15)	−0.087	(−1.12)
Risk variables						
Precipitation in last 72 hours (mm)	−0.015***	(−5.43)	−0.0073***	(−2.92)	−0.017***	(−5.92)
Advisory in place (0/1)			0.11	(0.91)	−0.39***	(−2.62)
Advisory 1 (June 3–5, 2004)	−0.67**	(−2.47)				
Advisory 2 (Dec. 29, 2004–Jan. 8, 2005)	−0.24	(−0.46)				
Advisory 3 (Jan. 12–20, 2005)	0.17	(1.07)				
Advisory 4 (Aug. 2–4, 2006)	−0.69	(−1.63)				
Advisory 5 (Apr. 11–13, 2007)	−0.88***	(−3.03)				
Advisory 6 (Jan. 9–11, 2008)	0.92***	(3.30)				
Advisory 7 (Jan. 30–Feb. 1, 2008)	0.45	(1.38)				
Advisories at other surfing beaches			0.11***	(3.64)		
Advisories at other swimming beaches					0.050***	(3.73)
Pseudo-R^2	0.39		0.34		0.39	

*Significant at $p < .10$.
**Significant at $p < .05$.
***Significant at $p < .001$.

were dropped. Coefficients on the day of the week dummy variables are relative to Friday, which was dropped. Results from alternative functional forms (robust negative binomial, robust OLS, tobit) are displayed for comparison (Table 3). In general the magnitudes and significance of coefficients are unaffected by alternative functional forms.

Results

Coefficients on the influence of meteorological variables on recreationist numbers showed expected signs and plausible magnitudes. As wave height increased, surfing increased up to a point, then declined as waves became too large to ride safely. As expected, factors that improve surfing conditions at Sands Beach—longer wave period, higher tide, and less wind—were correlated with a greater number of surfers. Wave height and period had a smaller influence on beachgoers than on surfers, and tide was not correlated with the number of beachgoers. Higher wind speed was correlated with fewer beachgoers. Warmer air temperature was correlated with more surfers and more beachgoers. Water temperature was not correlated with the number of surfers or beachgoers, likely because variations in water temperature were largely captured by the week of the year dummy variables. Increased cloud cover was correlated with fewer surfers and fewer beachgoers, although beachgoers were four times as responsive as surfers to cloud cover. More current precipitation was correlated with both fewer surfers and fewer beachgoers.

Coefficients on the influence of time-related dummy variables on recreationist numbers also showed expected signs and plausible magnitudes for both surfing and beach going. After controlling for meteorological conditions, surfer numbers steadily increased throughout the day, reaching a peak after 5 pm. Beachgoer numbers climbed throughout the morning, reached a peak in the early afternoon, and fell slowly throughout the afternoon. Controlling for other factors, both surfer and beachgoer numbers were highest on Saturday, followed by Sunday, Friday, and other weekdays. Controlling for other factors, surfer numbers were highest during fall quarter when new UCSB students are trying out surfing, and lowest during spring quarter. Controlling for other factors, beachgoer numbers were highest during spring and late summer. Both surfer and beachgoer numbers increased during holidays, when class was not in session, but decreased during vacations, when many students were out of town.

The 72 Hour Rule

The amount of rainfall in the previous 72 hours ("recent rainfall") was significantly correlated with fewer surfers and beachgoers. It was estimated that for every additional 25 millimeters of rainfall in the previous 72 hours, surfing decreased by 14.2%, while beach going decreased by 31.2%. Some portion of this decrease was ascribed to the impact of the 72 hour rule and not solely to unobservable declines in the recreational experience from wet sand and turbid water. Over the two years when water clarity data was available ($n = 2708$), decreased water clarity was correlated with significantly fewer surfers and beachgoers. But even after including water clarity as a regressor, the amount of recent rainfall remained significantly correlated with a decrease in surfer and beachgoer numbers. Including water clarity as a regressor caused a small but significant reduction in the effect of recent rainfall on surfing (coeff./std. error without clarity = −0.0162/0.0055; coeff./std. error with clarity = −0.0140/0.0055; $t = 14.7$) and on beach going (coeff./std. error without clarity = −0.0205/0.0045; coeff./std. error with clarity = −0.0190/0.0046; $t = 12.1$). The magnitude and significance of surfer and beachgoer responsiveness to rainfall drops off after 72 hours

Table 3
Surfer responsiveness to risk warnings under alternative functional forms

	Negative Binomial (Robust)		OLS (Robust)		Tobit	
Dependent variable	Surfers		Surfers		Surfers	
Number of observations	5980		5980		5980	
	Coefficient	z-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Constant	−2.22***	(−5.33)	−9.70***	(−3.42)	−26.13***	(−7.27)
Time of day						
Pre-7 am	−1.61***	(−15.44)	−6.84***	(−17.76)	−12.72***	(−18.74)
7–9 am	−0.92***	(−16.15)	−4.98***	(−14.48)	−7.13***	(−13.53)
9–11 am	−0.27***	(−5.36)	−1.95***	(−5.25)	−2.59***	(−5.10)
11 am–1 pm	(dropped)		(dropped)		(dropped)	
1–3 pm	0.14***	(2.93)	0.84**	(2.04)	1.25**	(2.48)
3–5 pm	0.33***	(5.97)	1.93***	(4.02)	2.88***	(5.02)
Post-5 pm	0.63***	(8.69)	4.74***	(5.96)	6.06***	(8.30)
Day of week						
Monday	−0.17**	(−2.56)	−1.45***	(−3.12)	−1.70***	(−2.83)
Tuesday	−0.30***	(−4.98)	−2.32***	(−5.51)	−3.13***	(−5.45)
Wednesday	−0.066	(−1.09)	−0.52	(−1.09)	−0.60	(−1.02)
Thursday	−0.055	(−0.96)	−0.73*	(−1.69)	−0.58	(−1.01)
Friday	(dropped)		(dropped)		(dropped)	
Saturday	0.26***	(4.51)	1.30***	(2.84)	2.13***	(3.70)
Sunday	0.19***	(3.23)	0.61	(1.29)	1.21**	(2.12)
Week of year dummy variables	Yes		Yes		Yes	
UCSB calendar						
Winter break	0.17	(0.89)	1.74	(1.06)	1.82	(0.90)
Spring break	−0.43**	(−2.20)	−2.46**	(−2.12)	−2.60	(−1.41)
Summer	0.088	(0.54)	0.075	(0.06)	0.63	(0.37)
Other holiday	0.42***	(3.59)	2.95**	(2.04)	4.14***	(3.20)
Finals week	0.48	(0.42)	1.07	(1.42)	0.51	(0.46)
Time trend (days)	-2.4×10^{-4}***	(−4.49)	−0.0019***	(−5.89)	−0.0025***	(−5.65)
Meteorological variables						
Wave height (m)	2.84***	(10.46)	17.00***	(12.50)	26.48***	(12.20)
Wave height squared (m^2)	−0.81***	(−5.88)	−4.64***	(−7.45)	−7.62***	(−7.41)
Wave height cubed (m^3)	0.061***	(2.97)	0.33***	(4.28)	0.58***	(4.07)
Wave period (sec)	0.061***	(8.13)	0.30***	(6.16)	0.47***	(7.11)
Tide (m)	0.55***	(13.55)	2.64***	(10.93)	4.70***	(13.90)
Wind speed (km/h)	−0.10***	(−7.78)	−0.64***	(−7.61)	−1.05***	(−9.38)
Water temperature (C)	0.010	(0.65)	−0.24**	(−2.26)	−0.088	(−0.68)
Air temperature (C)	0.035***	(5.57)	0.37***	(6.71)	0.41***	(6.46)
Cloud cover (/100%)	−0.16***	(−4.11)	−1.25***	(−4.73)	−1.59***	(−4.58)
Current precipitation (mm/hr)	−0.13**	(−2.00)	−0.25	(−1.22)	−0.50	(−0.90)
Risk Variables						
Precipitation in last 72 hours (mm)	−0.0054**	(−2.50)	−0.041***	(−3.67)	−0.069***	(−3.69)
Advisory in place (0/1)	0.16	(1.25)	1.85**	(2.20)	2.19*	(1.72)
R^2	0.07		0.32		0.07	

*Significant at $p < .10$.
**Significant at $p < .05$.
***Significant at $p < .001$.

(Table 4), supporting the hypothesis that the decline in surfing and beach going during the 72 hours following a rain was due at least in part to the 72 hour rule and not merely to decreased water clarity.

Beach Advisories

Beach advisories were not significantly correlated with a decrease in the number of beachgoers or surfers. In some model specifications, beach advisories were even significantly correlated with an increase in the number of surfers. This increase in surfers during beach advisories was significant using the OLS and tobit functional forms, but insignificant using the negative binomial functional form. The effect of beach advisories on surfers was insignificant when advisories were interacted with rainfall or season, or when the presence of beach advisories elsewhere in Santa Barbara County was included.

Beach advisories were correlated with a greater decline in surfer numbers during the dry season (May to October) than during the wet season (November to April), and with less rather than more rainfall in the previous 72 hours (Table 5). This suggests that surfers might perceive beach advisories after heavy rains as offering no additional information beyond that provide by the rainfall itself. An alternative explanation, that surfers may be less responsive during rainy winter months due to better waves at this time, is ruled out because beach advisories were correlated with fewer, rather than more, surfers when waves were higher (Table 5).

Surfer responsiveness varied widely across advisories, from an 87% decrease in surfing during the April 11–13, 2007 advisory, to a 112% increase in surfing during the January 12–20, 2005 advisory (Table 2). Beachgoer responsiveness also varied widely across advisories, from a 59% decrease in beach going during the August 2–4, 2006 advisory, to a 152% increase in beach going during the January 9–11, 2008 advisory. This range in responsiveness across advisories suggests that increases in surfing during certain beach advisories may have been due to unobserved increases in wave quality during those advisories rather than due to the advisories themselves.

Although most of the variables expected to influence the number of surfers are exogenous and observable, the number of surfers and beachgoers at every hour is not fully explained by observable variables. One omitted variable that is expected to predict wave quality is open ocean swell angle. Data on open ocean swell angle was not available from Buoy 46053 before 2008, and was not included. Local swell angle at Sands Beach, as predicted by the Coastal Data Information Program at Scripps Institute of Oceanography, was found not to be significant and was omitted from the regression. The quality of surfable waves is also influenced by the shape of the bottom contour, which shifts over time as sand is deposited and removed. No data is available on the shape of the bottom contour through time.

To test whether beach advisories at substitute sites increased surfer and beachgoer numbers at Sands Beach, data on beach advisories from the five other monitored surf beaches and the 20 other monitored swimming beaches in Santa Barbara County were included (Table 2). No data existed on surfer and swimmer numbers at these beaches. Meteorological conditions at these beaches are assumed to be similar to conditions at Sands Beach. An increase in the aggregate number of other beach advisories at substitute beaches was correlated with a significant increase in surfing and beach going at Sands Beach, suggesting that beach advisories at these substitute sites could be influencing recreational location choice. After beach advisories at substitute surf and swimming sites were explicitly included in the model, beach advisories at Sands Beach were found to be uncorrelated with surfer numbers, and found to be correlated with a significant decrease in beachgoer numbers.

Table 4
Surfer and beachgoer responsiveness to risk warnings by timing of precipitation

	Poisson (Robust)			
Dependent variable	Surfers		Beachgoers	
Number of observations	5980		5986	
	Coefficient	z-statistic	Coefficient	z-statistic
Constant	−1.28***	(3.41)	1.38***	(4.31)
Time of day				
Pre-7 am	−1.61***	(−15.15)	−1.90***	(−20.30)
7−9 am	−0.84***	(−15.23)	−1.28***	(−23.50)
9–11 am	−0.27***	(−5.74)	−0.67***	(−11.55)
11 am–1 pm	(dropped)		(dropped)	
1–3 pm	0.13***	(2.95)	0.61***	(13.37)
3–5 pm	0.26***	(5.18)	0.45***	(9.01)
Post-5 pm	0.55***	(7.77)	0.037	(0.55)
Day of week				
Monday	−0.19***	(−3.30)	−0.44***	(−6.90)
Tuesday	−0.30***	(−5.23)	−0.56***	(−9.02)
Wednesday	−0.048	(−0.84)	−0.39***	(−6.39)
Thursday	−0.072	(−1.32)	−0.37***	(−6.02)
Friday	(dropped)		(dropped)	
Saturday	0.18***	(3.37)	0.43***	(7.36)
Sunday	0.086	(1.58)	0.37***	(6.54)
Week of year dummy variables	Yes		Yes	
UCSB calendar				
Winter break	0.36**	(1.98)	−0.33	(−112)
Spring break	−0.47**	(−2.30)	−0.49**	(−2.08)
Summer	0.084	(0.56)	0.040	(0.27)
Other holiday	0.27**	(2.26)	0.77***	(5.97)
Finals week	0.20*	(1.84)	0.12	(0.98)
Time trend (days)	-3.1×10^{-4}***	(−6.88)	-2.4×10^{-4}***	(−5.15)
Meteorological variables				
Wave height (m)	2.81***	(12.61)	0.72***	(3.36)
Wave height squared (m^2)	−0.84***	(−8.22)	−0.27***	(−2.83)
Wave height cubed (m^3)	0.070***	(5.21)	0.029**	(2.34)
Wave period (sec)	0.043***	(6.70)	0.011*	(1.68)
Tide (m)	0.46***	(14.15)	-1.9×10^{-4}	(−0.00)
Wind speed (km/h)	−0.088***	(−7.39)	−0.085***	(−7.13)
Water temperature (C)	−0.0031	(−0.25)	−0.0017	(−0.14)
Air temperature (C)	0.038***	(6.38)	0.046***	(7.30)
Cloud cover (/100%)	−0.15***	(−4.07)	−0.61***	(−14.91)
Current precipitation (mm/hr)	−0.19**	(−2.03)	−0.11	(−1.39)

(Continued on next page)

Table 4
Surfer and beachgoer responsiveness to risk warnings by timing of precipitation (Continued)

	Poisson (Robust)			
Dependent variable	Surfers		Beachgoers	
Number of observations	5980		5986	
	Coefficient	z-statistic	Coefficient	z-statistic
Risk variables				
Precipitation in last 72 hours (mm)				
Precipitation in last 24 hours (mm)	−0.011**	(−2.04)	−0.020***	(−3.45)
Precipitation 24 to 48 hours ago (mm)	−0.0042	(−0.95)	−0.012**	(−2.34)
Precipitation 48 to 72 hours ago (mm)	−0.0040	(−1.28)	−0.016***	(−4.13)
Precipitation 72 to 96 hours ago (mm)	−0.0017	(−0.40)	0.0044	(0.92)
Precipitation 96 to 120 hours ago (mm)	0.0020	(0.68)	−0.0050*	(1.64)
Advisory in place (0/1)	0.24*	(1.87)	−0.066	(−0.50)
One day after advisory (0/1)				
Two days after advisory (0/1)				
Three days after advisory (0/1)				
Four after advisory (0/1)				
Five days after advisory (0/1)				
Six days after advisory (0/1)				
Seven days after advisory (0/1)				
Pseudo-R^2	0.34		0.39	

*Significant at $p < .10$.
**Significant at $p < .05$.
***Significant at $p < .001$.

Discussion

Surfers and beachgoers appear willing to engage in health risk–reducing avoiding behavior, because both the number of surfers and beachgoers significantly decreased in response to recent rainfall. This is likely at least partially attributable to the 72 hour rule, because recent rainfall remains significantly correlated with surfer numbers even after accounting for decreased water clarity, and because the effect of recent rainfall is no longer significant after 72 hours.

This revealed preference study shows similar levels of responsiveness to recent rainfall on the part of surfers to a stated preference study carried out at the same beach. Rumbley (2007) asked surfers at Sands Beach and four other nearby beaches whether they would surf on a day with perfect waves following an inch of rainfall the day before. One fifth of respondents stated they would definitely not surf, one quarter stated that they would definitely surf, and the remainder responded that it would depend on conditions. In comparison,

Table 5
Surfer responsiveness to risk warnings when beach advisories are interacted with other variables

	Poisson (Robust)					
Dependent variable	Surfers		Surfers		Surfers	
Number of observations	5980		5980		5980	
	Coefficient	z-statistic	Coefficient	z-statistic	Coefficient	z-statistic
Constant	−1.29***	(−3.45)	−1.27***	(−3.37)	−1.34***	(−3.58)
Time of day						
Pre-7 am	−1.61***	(−15.06)	−1.61***	(−15.14)	−1.61***	(−15.14)
7–9 am	−0.84***	(−15.18)	−0.85***	(−15.23)	−0.85***	(−15.24)
9–11 am	−0.26***	(−5.63)	−0.27***	(−5.69)	−0.27***	(−5.72)
11 am–1 pm						
1–3 pm	0.13***	(2.98)	0.13***	(2.98)	0.13***	(2.98)
3–5 pm	0.27***	(5.28)	0.26***	(5.24)	0.26***	(5.24)
Post-5 pm	0.55***	(7.81)	0.55***	(7.78)	0.55***	(7.85)
Day of week						
Monday	−0.20***	(−3.40)	−0.20***	(−3.36)	−0.19***	(−3.31)
Tuesday	−0.31***	(−5.42)	−0.31***	(−5.34)	−0.31***	(−5.29)
Wednesday	−0.055	(−0.95)	−0.053	(−0.92)	−0.041	(−0.71)
Thursday	−0.069	(−1.27)	−0.074	(−1.36)	−0.070	(−1.30)
Friday	(dropped)		(dropped)		(dropped)	
Saturday	0.18***	(3.28)	0.18***	(3.31)	0.18***	(3.40)
Sunday	0.080	(1.47)	0.082	(1.51)	0.084	(1.54)
Week of year dummy variables	Yes		Yes		Yes	
UCSB calendar						
Winter break	0.37**	(2.11)	0.36**	(2.03)	0.41**	(2.33)
Spring break	−0.47**	(−2.29)	−0.47**	(−2.31)	−0.45**	(−2.21)
Summer	0.081	(0.53)	0.077	(0.51)	0.098	(0.65)
Other holiday	0.26**	(2.19)	0.27**	(2.24)	0.26**	(2.20)
Finals week	0.19*	(1.73)	0.19*	(1.74)	0.22**	(2.02)
Time trend (days)	-3.1×10^{-4}***	(−6.68)	-3.2×10^{-4}***	(−6.94)	-3.1×10^{-4}***	(−6.79)
Meteorological variables						
Wave height (m)	2.80***	(12.60)	2.82***	(12.62)	2.81***	(12.68)
Wave height squared (m^2)	−0.83***	(−8.14)	−0.84***	(−8.19)	−0.83***	(−8.17)
Wave height cubed (m^3)	0.068***	(5.08)	0.070***	(5.13)	0.068***	(5.10)
Wave period (sec)	0.044***	(6.86)	0.043***	(6.71)	0.044***	(6.84)
Tide (m)	0.46***	(14.10)	0.46***	(14.10)	0.46***	(14.14)
Wind speed (km/h)	−0.087***	(−7.35)	−0.088***	(−7.42)	−0.087***	(−7.33)
Water temperature (C)	0.0016	(0.12)	−0.0031	(−0.25)	-6.4×10^{-4}	(−0.05)
Air temperature (C)	0.037***	(6.24)	0.037***	(6.35)	0.037***	(6.22)
Cloud cover (/100%)	−0.15***	(−4.20)	−0.15***	(−4.16)	−0.15***	(−4.19)
Current precipitation (mm/hr)	−0.21**	(−2.15)	−0.21**	(−2.17)	−0.21**	(−2.15)
Risk variables						
Precipitation in last 72 hours (mm)	−0.0067***	(−2.66)	−0.0063**	(−2.55)	−0.0056**	(−2.27)
Advisory in place (0/1)	−0.25	(−1.33)	−0.19	(−0.80)	1.29***	(5.50)
Advisory × precipitation in last 72 hours	0.044***	(3.61)				
Advisory × (November−April)			0.57**	(2.07)		
Advisory × wave height					−0.70***	(−4.47)
Pseudo-R^2	0.34		0.34		0.39	

*Significant at $p < .10$.
**Significant at $p < .05$.
***Significant at $p < .001$.

the current model found that the number of surfers decreased by 14.2% for each additional inch of rain in the previous 72 hours.

In contrast to recent rainfall, beach advisories were not significantly correlated with a decrease in the number of surfers or beachgoers. This finding is consistent with most other economic studies, which have found little if any public responsiveness to risk advisories. And it appears from surveys that while coastal marine water quality is an important factor in Southern California beach recreationists' site choice (Hanemann et al., 2004), the presence of a beach advisory is not (Lew & Larson, 2005).

Why would surfers and beachgoers at Sands Beach respond to the 72 hour rule but not to beach advisories? Perhaps recreationists are more easily convinced of illness risk based on what they can personally observe (recent rainfall), rather than what they can not personally observe (recent indicator organism concentration, as measured by a public health agency and publicized through the presence or absence of an advisory). Perhaps recreationists believe that the accuracy of the information provided by beach advisories is compromised by sampling error and long delay times. Or perhaps they believe that beach advisories provide no additional information about health risk beyond what can be observed from recent rainfall, as evidenced by higher responsiveness to beach advisories during dry periods. An effective health risk communication system would be convincing, accurate, and additional. Survey research could more clearly elicit recreationists' motivations for responding to the 72 hour rule but not to beach advisories.

There is reason to expect that recreationists at Sands Beach might be less responsive than recreationists elsewhere to beach advisories. Recreationists at Sands Beach may be less easily convinced of health risk than other recreationists due to their demographics or chosen recreational activity. Surfers at Sands Beach are likely to be younger (due to proximity to UCSB) and more male (males = 91%; Rumbley, 2007) than the general American population, and are selecting to take part in a moderately risky physical activity. A survey found that most Australian surfers did not wear protective headgear, not perceiving the risk of injury to be high enough to justify the impediments to the sport (Taylor et al., 2005). It is possible that recreationists of other demographics, or who swim or wade rather than surf, might be more responsive to beach advisories. Sands Beach is a relatively clean beach where beach advisories are relatively infrequent. It is possible that recreationists might be more responsive to beach advisories at a more frequently polluted beach. Beach advisories at Sands Beach may also be offering less additional information to beachgoers, due to the relatively high proportion of repeat visitors, who are likely to have more local experience and more private information regarding water quality and health risk. A beach advisory may have greater effect on recreation at a beach at which a higher proportion of recreationists are first-time visitors. Additional studies at other beaches where counts of recreationists are available could clarify whether responsiveness to beach advisories varies by recreationist demographic, recreational activity, frequency of advisories, or frequency of repeat visitation.

A stream of recent studies has assessed the welfare impact of beach advisories, weighing the benefits of avoided illnesses against the cost of foregone recreation (Rabinovici et al., 2004; Given et al., 2006; Pendleton, 2008). These studies found beach advisories to be welfare decreasing, but assumed complete or nearly complete responsiveness by recreationists to advisories. The lack of recreational responsiveness to beach advisories found at Sands Beach calls into question the assumption of nearly complete responsiveness, implying that advisories may have less welfare impact than previously estimated, at least at some beaches.

The BEACH Act mandated the EPA to develop new nationwide standards of water quality by 2005. This deadline was not met (USGAO, 2007). As new water quality monitoring and warning systems are developed, there is great scope for increasing the accuracy of information provided by beach advisories through more rapid and accurate sampling methods, more frequent sampling, predictive modeling, or probabilistic rather than binary risk notification. It would be expected that coastal recreationists would increase responsiveness to beach advisories, if they could be convinced that the advisories provide accurate and additional information on health risk. Sands Beach, or any beach with historical and ongoing recreationist counts, would be an ideal site to test the effect of an improvement to beach advisories on recreational responsiveness. In the mean time, surfers and beachgoers appear willing to engage in health risk-reducing avoiding behavior based on simple heuristics such as the 72 hour rule.

References

Boehm, A. B., S. B. Grant, J. H. Kim, S. L. Mowbray, C. D. McGee, C. D. Clark, D. M. Foley, and D. E. Wellman. 2002. Decadal and shorter period variability of surf zone water quality at Huntington Beach, California. *Environmental Science and Technology* 36(18): 3885–3892.

Brown, D. J., and L. F. Schrader. 1990. Cholesterol information and shell egg consumption. *American Journal of Agricultural Economics* 72(3):548–555.

Cabelli, V. J., A. P. Dufour, L. J. McCabe, and M. A. Levin. 1982. Swimming-associated gastroenteritis and water quality. *American Journal of Epidemiology* 115:606–616.

California State Department of Health Services (DHS): Statutes of 1997. Health and Safety Code 115880. Assembly Bill 411, Chapter 765.

California State Water Resources Control Board (CA SWRCB). 2009. Beach Surveys—Warnings, Closures, and Rain Advisories: Frequently Asked Questions. Available at http://www.waterboards.ca.gov/water_issues/programs/beaches/beach_surveys/docs/faqs.pdf (accessed April 2009).

Dorfman, M., and N. Stoner. 2007. *Testing the waters 2007: A guide to water quality at vacation beaches*. National Resources Defense Council, New York, New York, 377 p.

Dwight, R. H., D. B. Baker, J. C. Semenza, and B. H. Olson. 2004. Health effects associated with recreational coastal water use: Urban versus rural California. *American Journal of Public Health* 94(4):565–567.

Dwight, R. H., L. M. Fernandez, D. B. Baker, J. C. Semenza, and B. H. Olson. 2005. Estimating the economic burden from illnesses associated with recreational coastal water pollution—A case study in Orange County, California. *Journal of Environmental Management* 76(2):95–103.

Fenn, A. J., F. Antonovitz, and J. R. Schroeter. 2001. Cigarettes and addiction information: New evidence in support of the rational addiction model. *Economic Letters* 72:39–45.

Fleisher, J. M., D. Kay, M. D. Wyer, and A. F. Godfree. 1988. Estimates of the severity of illnesses associated with bathing in marine recreational waters contaminated with domestic sewage. *International Journal of Epidemiology* 27:722–726.

Frick, W. E., Z. Ge, and R. G. Zepp. 2008. Nowcasting and forecasting concentrations of biological contaminants at beaches: A feasibility and case study. *Environmental Science and Technology* 42(13):4818–2824.

Given, S., L. H. Pendleton, and A. B. Boehm. 2006. Regional public health cost estimates of contaminated coastal waters: A case study of gastroenteritis at Southern California beaches. *Environmental Science and Technology* 40:4851–4858.

Haab, T. C., and K. E. McConnell. 2002. *Valuing environmental and natural resources: The econometrics of non-market valuation*. Northampton, MA: Edward Elgar Publishing.

Haile, R. W., J. S. Witte, M. Gold, R. Cressey, C. McGee, R. C. Millikan, A. Glasser, N. Harawa, C. Ervin, P. Harmon, J. Harper, J. Dermand, J. Alamillo, K. Barrett, M. Nides, and G. Y. Wang. 1999. The health effects of swimming in ocean water contaminated by storm drain runoff. *Epidemiology* 10(4):355–363.

Hanemann, M., L. Pendleton, C. Mohn, J. Hilger, K. Kurisawa, D. Layton, C. Busch, and F. Vasquez. 2004. *Using revealed preference models to estimate the effect of coastal water quality on beach choice in Southern California*. Prepared for NOAA Minerals Management Service, California State Water Resources Control Board, and the California Department of Fish and Game.

Hou, D., S. J. M. Rabinovici, and A. B. Boehm. 2006. Enterococci predictions from partial least squares regression models in conjunction with a single-sample standard improve the efficacy of beach management advisories. *Environmental Science and Technology* 40(6):1737–1743.

Jakus, P. M., M. Downing, M. S. Bevelheimer, and J. M. Fly. 1997. Do sportfish consumption advisories affect reservoir anglers' site choice? *Agricultural and Resource Economics Review* 26(2):196–204.

Jakus, P. M., D. Dadakas, and J. M. Fly. 1998. Fish consumption advisories: Incorporating angler-specific knowledge, habits, and catch rates in a site choice model. *American Journal of Agricultural Economics* 80(5):1019–1024.

Kay, D., J. Fleisher, R. Salmon, F. Jones, M. Wyer, A. F. Godfree, Z. Zelenauch-Jacquotte, and R. Shore. 1994. Predicting likelihood of gastroenteritis from sea bathing: Results from randomized exposure. *Lancet* 344:904–909.

Kim, J. H., and S. B. Grant. 2004. Public mis-notification of coastal water quality: A probabilistic evaluation of posting errors at Huntington Beach, California. *Environmental Science and Technology* 38(9):2497–2504.

Lew, D. K., and D. M. Larson. 2005. Valuing recreation and amenities at San Diego County Beaches. *Coastal Management* 33(1):71–86.

MacDonald, H. F., and K. J. Boyle. 1997. Effect of a statewide sport fish consumption advisory on open-water fishing in Maine. *North American Journal of Fisheries Management* 17(3):687–695.

Mathios, A. D. 2000. The impact of mandatory disclosure laws on product choices: An analysis of the salad dressing market. *Journal of Law and Economics* 43:651–677.

May, H., and J. Burger. 1996. Fishing in a polluted estuary: Fishing behavior, fish consumption, and potential risk analysis. *Risk Analysis* 16(4):459–471.

Neidell, M. 2006. Public information and avoidance behavior: Do people respond to smog alerts? Working Paper.

Pendleton, L. 2008. The economics of using ocean observing systems to improve beach closure policy. *Coastal Management* 36:165–178.

Pruss, A. 1998. Review of epidemiological studies on health effects from exposure to recreational water. *International Journal of Epidemiology* 27:1–9.

Rabinovici, S. J., R. L. Bernknopf, A. M. Wein, D. L. Coursey, and R. L. Whitman. 2004. Economic and health risk trade-offs of swim closures at a Lake Michigan beach. *Environmental Science and Technology* 38(10):2737–2745.

Rumbley, J. L. 2007. An analysis of surfers' risk attitudes and behavior in Santa Barbara County and Ventura County. Unpublished masters' thesis, University of California, Santa Barbara.

Shimshack, J. P., M. W. Ward, and T. K. M. Beatty. 2007. Mercury advisories: Information, education, and fish consumption. *Journal of Environmental Economics and Management* 53(2):158–179.

Shuval, H. 2003. Estimating the global burden of thalassogenic diseases: Human infectious diseases caused by wastewater pollution of the marine environment. *Journal of Water Health* 1(2):53–64.

Sloan, F. A., V. K. Smith, and D. H. Taylor. 2002. Information, addiction, and 'bad choices': Lessons from a century of cigarettes. *Economic Letters* 77:147–155.

Smith, V. K., W. H. Desvousges, and J. W. Payne. 1995. Do risk information programs promote mitigating behavior? *Journal of Risk and Uncertainty* 10(3):203–221.

Speir, C. 2008. Estimating recreational anglers response to fish consumption advisories over time. Working Paper, University of Illinois.

Taylor, D. M., D. Bennett, M. Carter, D. Garewal, and C. Finch 2005. Perceptions of surfboard riders regarding the need for protective headgear. *Wilderness and Environmental Medicine* 16(2):75–80.

United States Government Accountability Office (USGAO). 2007. *Great Lakes: EPA and states have made progress in implementing the BEACH Act, but additional actions could improve public health protection*. Report to Congressional Requesters: 15–17.

Wade, T. J., N. Pai, J. Eisenberg, and J. Colford. 2003. Do US Environmental Protection Agency water quality guidelines for recreational waters prevent gastrointestinal illness? A systematic review and meta-analysis. *Environmental Health Perspectives* 111:1102–1109.

Wade, T. J., R. L. Calderon, E. Sams, M. Beach, K. P. Brenner, A. H. Williams, and A. P. Dufour. 2006. Rapidly measured indicators of recreational water quality are predictive of swimming-associated gastrointestinal illness. *Environmental Health Perspectives* 114(1): 24–28.

Wooldridge, J. M. 2002. *Econometric analysis of cross section and panel data*. Cambridge, MA: MIT Press.