NATIONAL WATER RESEARCH INSTITUTE
OCCASIONAL PAPER

# ASSESSING RISK INFORMATION CONCERNING COASTAL RUNOFF

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*Published by the*
National Water Research Institute

NWRI-2003-01

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## ACRONYMS

| | |
|---|---|
| CSUF | California State University Fullerton |
| ERM | Excess risk model |
| FC | Fecal coliform |
| HCGI | Highly credible gastrointestinal illness |
| ML | Milliliter |
| OCBC | Orange County Business Council |
| pfu | Plaque forming units |
| RR | Relative risk |
| SRD | Significant respiratory disease |
| TC | Total coliform |

ACKNOWLEDGEMENTS

The Principal Investigators on this project — William Blomquist, Harvey Collins, and David Friedman — gratefully acknowledge the support of the National Water Research Institute for Project Number KM-696-41-00, "Assessing Risk Information Concerning Coastal Runoff." We also appreciate the support of the Institute's cost-sharing partners, the County of Orange, Riverside County Flood Control and Water Conservation District, and the County of Los Angeles. Findings, conclusions, and other statements found in this report do not necessarily reflect the views of the National Water Research Institute or its cost-sharing partners.

Our compilation of the epidemiological literature on recreational water quality benefited immeasurably from the work of Ryan Dwight and David Turbow, graduate students in the Department of Environmental Analysis and Design in the School of Social Ecology at the University of California, Irvine. Dwight and Turbow, along with undergraduate student Sara Walker, also aided in the collection and analysis of news media reports for this project.

We also wish to gratefully acknowledge the computer access and other facilities provided by the School of Social Ecology at the University of California, Irvine, for research during fall 2000, as well as the extensive and efficient work of the Inter-Library Loan staff at the library of Indiana University-Purdue University at Indianapolis during spring and summer 2001.

## EXECUTIVE SUMMARY

In coastal urban watersheds, runoff from the landscape eventually reaches the ocean. If beaches along the ocean are used for recreation, three vital and interrelated questions arise. First, whether and to what extent does urban runoff degrade the quality of ocean water that is used for recreation? Second, to what extent does this runoff-related ocean pollution pose a risk to the health of recreational water users? Third, what sort(s) of policy response may be necessary to address runoff-related ocean water pollution and/or the health risks it poses?

It is commonplace to say that such decisions "should be based on science," but other factors are at play. One factor that may affect the development of policy responses to coastal runoff is the portrayal in the public domain of the connections between coastal urban runoff, ocean water quality, and health risks associated with recreational water contact. News media reports are one source of these portrayals when journalists report on beach warnings, closures, and related newsworthy events. Reports and press releases from other organizations (such as environmental groups and surfing or swimming clubs) are another source of these portrayals. Public officials may feel pressure to respond to these portrayals.

Lately, news media and other organizations have focused attention on coastal water quality and human health risks, especially in California, in connection with the sudden increase of health advisories posted at public beaches and the number of beach closures. That increase coincides with the implementation of California's recently enacted law (commonly referred to as AB 411 – Statutes of 1997) and regulations establishing statewide protocols for coastal water-quality testing and bacteriological water-quality standards. The rationale for the passage of AB 411, as well as for the regulations promulgated to implement the law's purpose, was to enact a set of risk-based coastal water-quality standards for recreational ocean water contact (swimming, surfing, etc.).

While the new law and regulations have prompted more health warnings and beach closures, public concern has also increased about coastal water quality (as measured by public opinion surveys). Beach closures and frequent advisories appear to have reduced attendance at public beaches and have harmed the economies of coastal communities that depend in part on beach-related tourism. The combination of public concern and economic impacts have prompted local public officials to respond to the issue of coastal water quality. A particular focus of attention has been coastal runoff — the water that reaches the coast from inland sources such as streams and storm channels, carrying pollutants from streets, landscaping, commercial activities, and even pets.

In the coastal urban watersheds of Southern California, a remarkable number of regulatory and remedial actions were undertaken concerning coastal runoff from mid-1998 through mid-2001. Millions of dollars of public funds have been devoted to a variety of efforts to reduce, intercept, divert, or treat urban runoff before it reaches the ocean, and millions more have been spent on efforts to improve ocean water-quality monitoring. New regulatory standards have been fashioned and adopted for reducing, capturing, or treating runoff before it reaches the coast. Residential and commercial development projects have been placed on hold by these new regulatory requirements as well as the more vigorous enforcement of existing ones. The anticipated costs of runoff reduction projects already planned or underway — and of meeting the new regulatory standards for new developments — run into the billions of dollars for Southern California alone.

An interesting question is whether these actions represent policy responses "based on science" or a reaction to perceptions in the public domain of the risks associated with coastal runoff. This report presents the results of a 10-month research project to address that question. The goals of the project have been to:

- Present an understandable and useful assessment of what is claimed and what is known concerning coastal runoff and the risks it poses to provide a source of perspective to policy makers and the public.
- Provide a framework for further research that could close identified gaps between what is claimed and what is known.

Using a specific time frame (June 1 to December 1, 1999) and two highly developed coastal urban regions for comparison (Southern California and Florida), we have compiled and analyzed a database of news media accounts of health risks associated with recreational ocean water contact. We found that runoff was the most frequently identified source of coastal water pollution in news media reporting and that urban runoff, in particular, was the most frequently mentioned type of runoff. News media reports connected runoff to the presence of high bacterial indicator levels in coastal water even though bacterial indicators used for coastal water monitoring are primarily intended to signal the presence of intestinal waste (sewage). We also found that most news reports from the period in question drew cause-and-effect connections between the presence of high bacterial indicator counts in recreational waters and human illnesses.

We have also analyzed health-risk information presented in the most widely used interest-group portrayal of those risks — the "beach report cards" issued by the environmental group, Heal the Bay. Heal the Bay's effort to produce an easy-to-understand guide for the public is laudable. Our review of Heal the Bay's methodology, however, suggests that because of the ways that measures from water-quality samples are translated into scores and letter grades, the beach report cards are likely to often misstate water quality at Southern California beaches, particularly the frequency with which water quality at a beach exceeds standards in AB 411 regulations. Because Heal the Bay's beach report cards are often cited in news media reports about health risks and coastal water quality, such reporting may present an exaggerated view of beach problems to the public.

We compared public portrayals of coastal water quality and health risks with "the science" (i.e., the body of published scientific research literature on the health risks associated with recreational ocean water contact) and then summarized and synthesized the published research on (a) the advantages and disadvantages of the various indicators that are and have been used to measure and assess ocean water quality, and (b) the epidemiological studies of the relationships between (i) exposure to ocean water of various levels of quality based on those indicators and (ii) the likelihood of developing symptoms of illness. Our report compares this synthesis of published literature on the health risks associated with ocean water contact with public-domain portrayals composed of media reporting and beach report cards. Our analysis is based on the state of that published literature and those public-domain portrayals as of the end of 2000.

We reviewed over 50 years worth of published scientific literature on bacterial indicators of ocean water pollution and on the health risks associated with recreational water-quality contact and found that while advances were made in water-quality monitoring during the twentieth century, there remain important sources of error that can produce either "false positives" (indications that water quality is impaired when it is not) or "false negatives" (indications that water quality is acceptable when it is not).

Sampling and measurement errors — and even the delay between the time when a water-quality sample is taken and the time when laboratory results are returned — can result in beaches being posted as unsafe when they are not or going unposted when they should be. These error factors would exist even if water quality was monitored directly for each pathogenic organism that might be present in a water body. Instead, because monitoring for each potential pathogen would be unreasonably expensive and time-consuming even if it were possible, bacteriological water-quality indicators (specifically coliform bacteria and/or *Enterococcus* bacteria) are relied on instead. Research on (and the use of) water-quality indicators dates back 100 years, and there are sound bases for using them. But the use of water-quality indicators does introduce yet another error factor into water-quality monitoring: these bacteriological indicators are only correlated with the presence of actual pathogens, so indicator concentrations in a water sample may be high even when pathogen concentrations are low, or vice versa.

One noteworthy feature of the AB 411 regulations in California was the addition of *Enterococci* as a bacteriological water-quality indicator in the coastal water-monitoring program. *Enterococci* concentrations exceeding the regulatory standards have accounted for the great majority of posted beach warnings and beach closures since the regulations took effect in 1999. Yet, it appears from our review of the scientific research literature on water-quality testing in ocean water that the addition of *Enterococci* to California's coastal water-monitoring program was based on sound considerations. *Enterococci* share some of the desirable properties of coliform bacteria (specifically, being comparatively easy to colonize and count), but have other properties that make them preferable to coliforms as water-quality indicators in salt water. Thus, the inclusion of *Enterococci* as an indicator in AB 411 may have triggered more beach warnings and closures, but may also have represented an improvement in the water-quality monitoring program.

Still, both coliforms and *Enterococci* have substantial weaknesses in identifying the risk of illness from recreational water contact, such as:

- First, these indicators were identified and originally used to detect fecal contamination of drinking water and, therefore, the risk of gastrointestinal illness from the direct ingestion of water. While swimmers and surfers undoubtedly do ingest some water during recreation, the quantities of ocean water swallowed by a swimmer or surfer are likely to be small compared with directly ingesting drinking water.
- Second, most of the illness symptoms reported by recreational water users are not gastrointestinal. The most common complaints of recreational water users are respiratory illness, eye or ear irritation or infection, and skin rashes. It is not clear that indicators of fecal contamination related to gastrointestinal illness correlate well with pathogens in recreational water that may be causing these non-gastrointestinal symptoms.
- Third, coliform and *Enterococci* indicators do not directly detect the presence of viruses in recreational waters and do not appear to correlate well with virus presence, either.
- Fourth, coliform and *Enterococci* indicators do not detect the presence of non-organic contaminants (e.g., metals, petroleum products, chemical fertilizers and pesticides, etc.), which may be present in coastal urban runoff and may also pose as-yet undetermined health risks to recreational water users.

Despite these weaknesses, bacteriological water-quality indicators have been associated with illness symptoms experienced by recreational water users. Epidemiological studies comparing recreational water quality and illness among swimmers have been conducted for more than 50 years, in several countries, using a variety of study designs. As might be expected from such a body of research, there have been several studies that did not find a relationship between bacteriological indicators and illness symptoms reported by swimmers compared with non-swimmers. But a review of 22 epidemiological studies published between 1948 to 1996 showed that 19 of the 22 studies found statistically significant relationships between indicator concentrations and illness symptoms. Of course, these relationships are correlations only; epidemiological studies can find associations, but do not generate the cause-and-effect evidence of the etiology of illness generation.

Our report pays particular attention to the Santa Monica Bay Epidemiological Study conducted by Haile et al. (1999). The Santa Monica Bay Epidemiological Study stands out for at least three reasons:

- First, it focused upon recreational waters receiving storm-drain discharges, as opposed to sewage discharges that were the focus of other epidemiological studies; therefore, the Santa Monica Bay Epidemiological Study is arguably more relevant to the question of health risks associated with runoff-impaired coastal water quality.
- Second, the Santa Monica Bay Epidemiological Study is the most recent large-scale epidemiological study of swimming-associated health risk.
- Third, having been conducted in coastal Southern California, the Santa Monica Bay Epidemiological Study is understood to have strongly influenced the California Legislature's adoption of AB 411 in 1997 and the California Department of Health Services' promulgation of regulations in 1999.

The Santa Monica Bay Epidemiological Study is often cited in news reports as "proving" that contaminated runoff or storm-drain discharge "causes" increased illnesses among recreational water users. It is also often described as showing that swimming "near" storm drains raises the risk of illness for beachgoers. And its findings are presented as if they were applicable to the entire Southern California coast. In these respects, the treatment of the study's findings in news reports has gone far beyond the researchers' own reporting of (or claims about) their findings.

In fact, the findings of the Santa Monica Bay Epidemiological Study are more tentative and mixed than commonly reported. For example, rather than experiencing the highest risk of illness, those swimming "near" the storm drains in the study (i.e., within 50 or 100 yards of a drain) had the *lowest* rates of illness of any group in the study, including the control group. The greatest frequencies of illness symptoms appeared among two groups of subjects in the study: first, 7 percent of subjects who were observed swimming *directly in front of* a flowing storm drain and, second, the control group of subjects who swam *400 yards or more away from* the drains. Finally, the beach conditions that were the focus of the Santa Monica Bay Epidemiological Study (i.e., locations within 100 yards of a perennially flowing storm drain) do not characterize the entire Southern California coast or even most of it. Less than 4 percent of the entire Southern California coast shares the conditions of the locations included in the Santa Monica Bay Epidemiological Study.

Overall, relying upon current bacteriological water-quality indicators creates substantial dilemmas for local officials attempting to respond to demands for water-quality improvements. On the one hand, there is a substantial body of research showing relationships between indicator concentrations and (at least, gastrointestinal) illness symptoms among recreational water users.  And high indicator counts trigger beach warnings and closures, stimulating public pressure for actions (even very expensive actions) to improve water quality.  On the other hand, there is considerable uncertainty about the connections between these water-quality indicators and the particular types of illness symptoms most commonly reported by recreational water users, and the connections are even more uncertain or nonexistent between these water-quality indicators and viral or toxic contaminants; therefore, it is possible that actions taken to reduce the concentrations of these bacterial indicators may not reduce the health risks most often experienced by recreational water users.

It is fairly certain that news media reports about the risks associated with bacterial indicators of coastal water quality simplify and overstate the case, compared with what may be found in published scientific literature.  As noted above, a majority of the news reports that were analyzed drew cause-and-effect connections between the presence of indicator bacteria and illnesses experienced by recreational water users.  Such claims go beyond what established science can support.

Finally, this report analyses the financial and public-policy consequences of basing policy responses on one set of portrayals compared with the other.  To put it another way, we attempt to answer the “who cares?” question.

We have extrapolated from the Santa Monica Bay Epidemiological Study the potential number of excess illnesses associated with impaired recreational water quality for the entire Los Angeles County coastline.  In doing so, we made conservative assumptions that would tend to increase the estimate of illnesses rather than diminish them.  Drawing upon other published literature on the estimated direct and indirect costs of illnesses, we have estimated the financial consequences associated with those anticipated excess illnesses: if water-quality improvements could eliminate *all* excess illnesses, the benefits (in terms of avoided costs of those illnesses) could reach a maximum of $35-million per year.  The expected costs, however, of water-quality improvement measures currently planned or underway exceed those estimated benefits (e.g., the estimated cost of the Los Angeles Regional Water Quality Control Board’s plan to eliminate trash from the Los Angeles River over the next 10 years is approximately $1.75 billion, or $175 million per year).  Thus, the estimated costs of that one measure alone would far exceed our highest estimate of the benefits in terms of reduced health risks from recreational water contact.

By estimating the costs associated with reducing coastal runoff in Southern California relative to the health benefits achieved, our report attempts to provide an alternative perspective to the policy debate on what to do about coastal runoff in Southern California and, presumably, other coastal urban watersheds.  We recognize, of course, that factors other than expected costs and benefits are probably driving decision-making processes regarding runoff reduction and coastal water-quality improvement.  Those factors are probably attributable to public perception of health risks, which may have been shaped by the risk information that has been communicated to them.

# CHAPTER ONE
# CLOSURES, PERCEPTIONS, RISKS, AND REGULATIONS

*"Are surfers and others who frequent the ocean*
*playing Russian roulette with their health each time they get wet?*
*Maybe so…."*
~San Diego Union-Tribune,
*June 20, 2000*

Statements such as this one in news articles question the safety of beach recreation and ocean water contact. As the references to this report demonstrate, dozens of articles on this topic appeared in Southern California from 1998 to the present. This research project was developed and undertaken to review information presented to the public about the health risks of ocean water contact and to compare that information with scientific literature on the topic. This chapter describes the context that gave rise to this report.

## 1. A Surge at the Beaches

Southern California's coastline and beaches are among its greatest assets and attractions. Surfing, swimming, sunbathing, beach volleyball, cookouts, sunset walks, and beachfront homes and resorts are part of the area's image and are closely associated with its perceived quality of life.

Beach visits by tourists and local residents are estimated in the tens of millions per year. Money spent on food, lodging, souvenirs, and so forth during all those visits makes the beach business a billion-dollar-plus component of the Southern California economy.

Not surprisingly, beach closures have long been a source of concern in Southern California. Beaches have been closed from time to time by oil spills from offshore tankers, sewage leaks from onshore communities, and debris sent crashing across the beaches by large storms that overwhelm inland channels and impoundments. Events such as these render ocean water unfit for recreation, sometimes for days or even weeks. When public health officials declare the water closed to recreation, the number of beach visitors drops.

Beach closures are not new, but the last couple of years have been different. A major El Niño season in the winter and spring of 1998 battered the coast. The rains from those storms swept across the urban coastal landscape and filled storm drains, channels, creeks, and rivers. As these flows reached the ocean, they often produced high bacterial counts that prompted public health officials to declare beaches off-limits to water recreation until bacteria concentrations subsided. California recorded 3,273 temporary beach closures in 1998, nearly triple the 1997 total and more than double the number of any year in the previous decade.

In a way, 1999 was even more unusual. The weather returned to normal, but the number of beach closures remained just as high — 3,547 temporary beach closures statewide. What could account for such a huge number in a relatively normal weather year? It seems unlikely that ocean water quality in California could have plummeted in such a way that the closures in 1999 were triple the number in 1997, 1996, or 1995, and nearly quadruple the number in 1994.

## 2. A New Sheriff in Town

The 1999 experience appears to be related to the beginning of a new ocean water testing program. In 1997, the California Legislature had passed Assembly Bill 411, "State Regulation of Beaches and Recreational Waters" (still commonly referred to as AB 411).[1] The California Department of Health Services then promulgated regulations to implement the statute, and the regulations took effect July 26, 1999.

The stated purposes of AB 411 were to:

- Standardize what had been a diverse, county-by-county approach to ocean water-quality testing.
- Fashion and enforce bacteriological water-quality standards based on human health risks associated with recreational water contact.

The law and its regulations required coastal counties to sample ocean water more often and test for more contaminants, revised the standards for microbiological contaminants in ocean water, and established new procedures for warning the public about the quality of water and for closing it to public access. County officials are required to post warnings, advising the public that water may not be suitable for swimming or other recreational contact when the quantities of microbiological indicator organisms exceed levels recommended in the regulations. Beach closures are required when county officials have reason to believe that untreated sewage has reached coastal water, and county officials have discretion under the law to close beaches when they have reasons to believe that contact with the water is unsuitable.

The impact of AB 411 is most evident when its first year of implementation (July 1999 to June 2000) is compared with the prior year (July 1998 to June 1999). According to figures published by the Orange County Health Care Agency, beach closures in Orange County alone more than doubled from 15 in 1998/1999 to 38 in 1999/2000, and the number of beach-closure days[2] jumped from 133 to 250. More frequent bacteriological testing and stricter limits resulted in an increase in beach closings that would not have been expected based on weather or other factors.

New beach warnings provided for in AB 411 further demonstrate the law's impact. Under AB 411, county health officials are required to post warnings when certain bacteriological water-quality indicators exceed limits set by the California Department of Health Services, even though conditions may not require closing the water to human contact. AB 411 is sometimes described as a "right-to-know" law because it incorporates this feature of warning the public of impaired water quality even though a beach may not need to be closed.

Under AB 411, county officials must monitor total coliform (TC), fecal coliform (FC), and *Enterococci* bacteria in ocean water samples and post warnings if any of the three exceed limits set by the state health department. The *Enterococci* bacteria were added to California's ocean water-quality testing by AB 411. Previously, county health officials relied on TC and/or FC counts only.[3]

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1 Statutes of 1997, Chapter 765, now codified in the California Health and Safety Code, Division 104, Part 10, Chapter 5, Article 2, Section 115875-115915 inclusive.

2 Beach-closure days combine the number of days of closure for each beach closed. For example, one beach closed for 4 days and another closed for 6 days yields 10 beach-closure days.

3 Chapter 4 describes these water-quality indicators more thoroughly, including how and why they are used and an assessment of their strengths and weaknesses as indicators of the health risks associated with water contact.

The addition of *Enterococci* bacteria mattered. In the first year of AB 411's implementation, warnings were posted at Orange County beaches 360 times. *Enterococci*, the new indicator, was involved in 276 of those 360 postings, compared to 153 postings for high FC counts and 65 for high TC counts.[4]

### 3. The Public Engages

The record numbers of beach closures in 1998 and 1999 — and the new phenomenon beginning in mid-1999 of frequently posted health warnings even at beaches that were open — drew the attention of the Southern California news media. The closures, the warnings, and the topic of ocean pollution with which they were linked became the subjects of many articles and broadcasts. Regional newspapers such as the *Orange County Register* began featuring a map in every daily edition, showing the spots along the coast where warnings had been posted or closings had occurred.

The national news media were drawn to the story when Huntington State Beach in the City of Huntington Beach — renowned as "Surf City USA" — was closed for much of the summer of 1999, from the Fourth of July weekend to the threshold of Labor Day. August 1999 attendance at Huntington State Beach was down 45 percent compared to the same month the previous year. Beach-related businesses were substantially harmed. The Huntington Beach story gave the beach closure trend a focusing event and generated nationwide coverage on the major broadcast news programs and in national newspapers such as the *New York Times* and *Christian Science Monitor*.

The warnings and closures, combined with press coverage, had an impact on the general public. The University of Southern California's Southern California Beach Project conducted an Environmental Perceptions Survey of 403 randomly selected Los Angeles County households during July, August, and September 1999. More than half (50.86 percent) of the individuals who responded remembered seeing a "no swimming" warning sign at a beach that they had visited. Two-thirds of all respondents (68.24 percent) recalled hearing about a beach closure within the prior year, and nearly three-quarters (73.45 percent) remembered seeing or hearing a news story about water quality at one or more beaches (Pendleton et al., 2001).

The level of awareness regarding the warnings and closures is consistent with a public perception that the problem is "bad and getting worse." A survey of Orange County residents in August 2000 for the Orange County Business Council (OCBC), conducted by the Social Survey Research Center at California State University Fullerton (CSUF), found extremely high levels of reported public concern about beach closures. More than 80 percent of 556 respondents expressed the view that beach closures were a "serious" or "very serious" problem, with 53.7 percent responding "very serious" (Orange County Business Council, 2000; Brennan, 2000c).

The spikes in beach closures and warnings in 1998 and 1999, and the attention paid to those closures and warnings, can be reasonably associated with a public perception that ocean water quality is deteriorating. Nearly three-fifths of the respondents (58.06 percent) in the University of Southern California Environmental Perceptions Survey said that they thought ocean water quality had become worse during the preceding 5 years. About one in five (19.85 percent) thought ocean water quality had improved. Furthermore, the survey respondents held more negative views of ocean water-quality trends than of air quality. About half (49.13 percent) of the same respondents thought air quality had worsened in the preceding 5 years, but nearly two-fifths (37.71 percent) thought it had improved (Pendleton et al., 2001).

4 The numbers for the three bacterial indicators sum to more than the 360 posted warnings because water-quality samples could exceed the warning levels for more than one of the indicators. For instance, both FC and *Enterococci* readings from samples could have surpassed regulatory limits and prompted a warning.

Being aware of or concerned about a regional problem is not necessarily the same as feeling personally affected by it. By the summers of 1999 and 2000, however, a substantial portion of residents reported that they were adjusting their own behavior as a result of their perceptions of ocean pollution. Concerns about water pollution were by far the most common reason given by regular beachgoers[5] in the 1999 University of Southern California survey for not entering the water. Most regular beachgoers said they do not enter the water when they visit the beach,[6] and 45 percent of those said water pollution was why they stay out.[7] Respondents in the August 2000 OCBC/CSUF survey were more closely divided about whether ocean water pollution had discouraged them from visiting the beach. A majority (54 percent) disagreed that pollution had reduced their beach visits, but a sizable minority (46 percent) agreed that they visit the beach less often because of pollution[8] (Orange County Business Council, 2000).

The August 2000 OCBC/CSUF survey also asked Orange County residents about perceived causes of the rise in beach closures. Respondents were given a list of nine potential causes and allowed to label them as "very," "somewhat," or "not" important in contributing to the problem. The proportions rating each prospective cause as "very" or "somewhat" important were as follows (Brennan, 2000c):

| | |
|---|---|
| Runoff of polluted water and waste. | 98 percent |
| Inadequate sewer and drain systems. | 96 percent |
| Improper use of storm drains by residents. | 96 percent |
| Weak enforcement of environmental regulations. | 94 percent |
| Better water-quality testing procedures. | 92 percent |
| Tougher water-quality standards. | 91 percent |
| Dog waste and other materials at/near beach. | 91 percent |
| Too much unplanned growth. | 89 percent |
| Carelessness of beach users. | 86 percent |

It is noteworthy that 91 and 92 percent of the respondents, respectively, recognized that beach closures were more frequent because of tougher water-quality standards and improvements to the water testing program. Nevertheless, equal or higher proportions of the respondents blamed the rise in beach closures also on improper waste disposal practices, inadequate facilities and enforcement, and on growth and runoff.

In other words, these Orange County residents seemed to understand that beach closures were increasing due to the new regulatory scheme, but they also appeared to believe that ocean water quality really was in danger, and they were unwilling to accept the status quo. Respondents from both beach and inland cities expressed a desire to see actions taken to improve ocean water quality, a willingness to pay more in taxes for those actions, and support for sharing the costs equally across the county.

In a February/March 2000 survey of registered voters in Orange County, 62 percent of the respondents stated that they would be willing to pay 1 percent more per year in taxes to clean up coastal waters. That issue received a higher level of support than improving water and sewer systems (58 percent), reducing most road congestion (53 percent), keeping roads and bridges

5 Those who said they visit the beach at least once per month during a typical summer.

6 Fewer than half (38.46 percent) of those who visit the beach said they enter the water.

7 Aversion to water, the next most common reason for staying out, was given by 22.88 percent of respondents — approximately half the number citing pollution concerns.

8 Those responding to the Orange County survey were also more likely to report that they enter the water when they visit the beach. Only 20 percent of the Orange County survey respondents said they "never" enter the water.

free of graffiti (50 percent), or improving the level of public transit service (44 percent). Respondents in the August 2000 OCBC/CSUF survey were offered five options for distributing the costs of coastal water-quality improvement and asked which option they supported most. The percentages were as follows:

| | |
|---|---|
| All residents equally. | 72.5 percent |
| All residents, but beach areas pay more than inland areas. | 15.6 percent |
| Beach-area residents only. | 8.7 percent |
| All residents, but inland areas pay more than beach areas. | 2.2 percent |
| Inland-area residents only. | 1.0 percent |

Local and state officials are well aware that residents not only desire improvement, but also are willing to pay for these improvements; therefore, the beach-closure issue received a great deal of attention from local and state officials, including legislative measures and funding for studies and possible remedies. The efforts of public officials to respond to the beach problems were rated favorably ("well" or "very well") by 61 percent of the OCBC/CSUF Orange County respondents and were rated unfavorably ("poor" or "very poor") by 31 percent.

### 4. Coastal Runoff Becomes the Story

Much of this attention and activity focused on coastal runoff — the water that is shed from the rooftops and landscaping of coastal and inland communities, from parking lots and streets, down gutters and storm drains, and emptying untreated into creeks, streams, and estuaries, eventually finding its way across beaches and into the ocean. News reports in recent years have named runoff as Southern California's greatest ocean pollution source and stated that Southern California has the worst runoff problem in the United States:

> Although cities across the nation are plagued by polluted runoff, Southern California remains the biggest battleground. The paved urban sprawl produces the perfect environment…
>
> Last year, tainted runoff shut down 30 different strips of California coastline for at least 6 weeks. A dozen others were closed for 3 months or longer (Bailey, 1999).
>
> The Los Angeles area is believed to suffer the worst runoff problem in the country, with viruses and toxic pollutants flowing to the ocean on dry as well as rainy days (Cone, 1999a).
>
> Urban runoff — one of the few U.S. environmental problems still getting worse — is the nation's No. 1 source of pollution fouling waterways (Cone, 1999b).

Residents and public officials have received the message. Runoff topped the list of beach-closure culprits in the OCBC/CSUF survey, being named as an "important" or "very important" contributor by a phenomenal 98 percent of the respondents in the OCBC/CSUF survey. By the time that survey was taken (August 2000), federal, state, and local regulators and other officials were promoting runoff reduction, diversion, impoundment, and treatment options.

Runoff's rapid rise to prominence as an ocean pollution source resulted from an accumulation of events and trends over a period of 25 years or so, including:

- The success of the federal Clean Water Act during the 1970s and 1980s in reducing the discharge of inadequately treated sewage to the ocean.
- The accelerated urbanization of coastal areas since the 1970s.
- The adoption in 1990 of new federal requirements to address non-point sources of water pollution.
- An epidemiological study of swimmers in Santa Monica Bay in the early 1990s that associated illness risk with storm-drain outfalls.
- Effective advocacy by several groups during the 1990s and since to bring attention to runoff as a pollution source and potential health hazard.

The implementation and enforcement of the provisions of the Clean Water Act since 1972 addressed one of the most obvious sources of illness-threatening pollution — the disposal of inadequately treated human sewage into rivers, streams, and the ocean. The act targeted these and other "point sources" of pollution (e.g., identifiable pipes spewing pollutants). The Clean Water Act succeeded in spurring the transition of municipal wastewater systems to more advanced treatment. As the health threat from this pollution source diminished, the attention of public health officials, scientists, and others turned to other pollution sources, including diffuse or "nonpoint" sources such as agricultural and urban runoff.

Urban runoff has gathered more attention recently in coastal areas partly because of the continuing urbanization of the coastal United States. Despite high real-estate prices and exposure to damaging storms and floods, coastal areas have absorbed a rising proportion of the growing United States population. The concentration of Americans in urbanized coastal regions intensified in the 1980s and 1990s. Today, half of the nation's 280-million residents live within 80 miles of the shoreline, and 19 of the 20 most densely populated counties in the United States are coastal counties. There are no signs of this trend abating. Census figures indicate that from 1990 to 2000, 17 of the 20 fastest-growing counties, as well as 16 of the 20 counties with the largest number of new housing units under construction, were located along the coast (http://state-of-coast.noaa.gov/bulletins/html/par_02/national.html).

What difference does the intensive urbanization of a coastal region make? If nothing else, the sheer volume of coastal runoff (and the constituents carried in the flow) accelerates at a comparable or greater pace. According to the Southern California Coastal Water Research Project, the volume of runoff from Southern California (Ventura County to the Mexican border) into the Pacific Ocean catapulted from about 65-billion gallons per year in 1972 to approximately 1-trillion gallons in 1997 (Cone, 1999b) — a 15-fold increase in 25 years. This connection between urban development density and runoff volume has supported the growth in attention to runoff as a potential source of ocean pollution near urbanized coastal areas.

In 1990, this attention translated into a federal mandate to states to develop plans for controlling runoff and other potential nonpoint threats to coastal water quality. These amendments to the federal Clean Water Act not only stimulated the development of plans by state governments, but also provided leverage for potential litigation by groups in states that were perceived as delaying coastal runoff control programs. In California, for example, the Natural Resources Defense Council threatened the state with litigation in 1997 for having failed to produce a federally-approved plan 7 years after the issuance of the federal mandate.

In Southern California, a large-scale epidemiological survey was conducted in 1992 of swimmers at selected sites along Santa Monica Bay. Findings from the study appeared in reports issued by the Santa Monica Bay Restoration Project in 1994 and 1995, and were published in the journal *Epidemiology* in 1996.[9] One of the reported findings was that

9 The Santa Monica Bay Epidemiological Study is considered in greater depth in Chapters 5 and 6 of this report.

swimmers who swam in front of storm drains, which convey runoff to the ocean, were more likely than swimmers at other distances to report illness symptoms after swimming. The Santa Monica Bay Epidemiological Study increased the attention to runoff, not only as a potential source of ocean water pollution that was increasing with urbanization, but also as a pollution source with possible human health consequences.

Coastal-zone protection advocacy groups have skillfully communicated to the public the importance of runoff and its connection to urbanization, the 1990 federal mandate and the responsibility of states and local governments to address it, and the Santa Monica Bay Epidemiological Study. Some groups are national in scope and operation, such as the Natural Resources Defense Council and the Surfrider Foundation, while others are networks of local groups such as the CoastKeeper chapters, and still others are entirely local (such as Southern California's Heal the Bay, Defend the Bay, and Clean Water Now). All have produced and disseminated information — directly to the public and indirectly through news reporting — that draws connections between runoff, ocean water quality, and human health risks.

### 5. The Runoff Battle: Many Fronts, Multiple Strategies

This connection has drawn a policy response from public officials that can modestly be described as massive. A comprehensive list or description would overwhelm this report and any reader. For the sake of simplicity, we will categorize the policy responses as research, regulation, and remediation, and provide some examples of each.

***Research***

Local governments, the State of California, and the region's universities have responded to the beach closure/coastal runoff problem by undertaking additional studies to obtain the scientific information needed to support sound decision making. Studies include:

- A consortium of coastal counties and water agencies funds the work of a non-partisan "think tank" known as the Southern California Coastal Water Research Project. The project maintains a staff of professional researchers from several science disciplines who study the region's coastal water quality, including its implications for the health of people and marine life, and have undertaken comprehensive monitoring programs along the entire Southern California bight.
- The County of Orange, the Orange County Sanitation District, and several coastal Southern California cities have worked with the National Water Research Institute to fund investigations of the possible causes of the high bacterial indicator counts that contributed to the extended closure of Huntington State Beach during the summer of 1999. Those studies are now in their third year. Research teams from the University of California, Irvine, and the University of Southern California were deployed to conduct these studies.
- The civil Grand Juries of Los Angeles, Orange, and San Diego counties have each conducted investigations and published reports on ocean water-quality testing and public information programs, and on the possible sources of ocean pollution that lead to beach warnings and closures.
- The University of Southern California and the Wrigley Institute for the Environment established the Southern California Beach Project, and the University of California, Irvine, proposed the creation of both a Clean Beach Center and an Urban Water Research Center to conduct science and policy research related to the coastal environment.

***Regulation***

Local and state government agencies have adopted new regulations, revised existing ones, and/or increased enforcement capability regarding runoff controls and the use of storm drains for dumping. Examples include:

- The State of California increased funding for enforcement staff at all the regional water-quality control boards beginning in the 1999-2000 fiscal year.
- In 2000, the Los Angeles Regional Water Quality Control Board adopted a 10-year plan to require cities to reduce urban runoff, complete with permit requirements for new development and large-scale redevelopment.
- In February 2001, the San Diego Regional Water Quality Control Board adopted a similar plan for its region. The new stormwater permit would:
    a. Require that local governments oversee urban runoff discharges.
    b. Require local governments and agencies to institute management practices that reduce polluted runoff flows in conjunction with development planning, construction, and resulting land uses.
    c. Set up specific water-quality standards for stormwater discharges.
    d. Prohibit non-storm runoff discharges into drainage basins.
    e. Require local governments and agencies to ensure that runoff discharges do not deteriorate water-quality below standards and to eliminate sources of illicit discharges.
    f. Require local governments and agencies to establish an urban runoff management program and participate in creating a more widespread management program for each watershed.
    g. Require local governments and agencies to create an extensive water-quality monitoring program for water-quality objectives.
- The Santa Ana Regional Water Quality Control Board has increased the frequency and amounts of fines it levies for violations of stormwater permits.
- The City of Santa Monica's 1992 stormwater reduction ordinance requires supplemental drainage systems. It applies to new construction and to major renovations of existing homes.

***Remediation***

Numerous efforts are directed toward capturing runoff in coastal creeks and storm drains, and either treating the runoff water onsite or diverting it to a sewer system for treatment.

- In May 2001, the City of Santa Monica completed a new plant to capture, treat, and reuse runoff water.
- The Los Angeles County Department of Public Works has built four diversion projects along Santa Monica Bay to collect storm-drain flows and send them to the department's sewage treatment plants for treatment prior to ocean disposal.
- The Cities of Los Angeles and Santa Monica, which have their own sewage treatment plants, have also undertaken storm-drain diversion projects.
- The Orange County Sanitation District accepts up to 4-million gallons per day of diverted storm-drain flows during the dry season for treatment prior to disposal through the district's ocean outfall. The City of Huntington Beach began diverting storm-drain flows to the Orange County Sanitation District in August 1999. The County of Orange constructed berms across the lower reach of the Santa Ana River channel to impound dry-weather river flows (composed primarily of urban runoff) and divert them to the Orange County Sanitation District's treatment facility.

- The City of Laguna Beach currently captures and treats 38 percent of its dry-season storm-drain flow and plans to increase that to 100 percent by 2007.
- In January 2000, officials from the City of Malibu began installing ultraviolet light and ozone sanitizing equipment to treat storm-drain runoff at three locations. The projects are expected to be completed in early 2003.
- Several cities, some counties, and Caltrans have installed filters in stormwater drains to screen pollutants from street-level runoff.
- Trash booms have been placed across Ballona Creek and the lower reach of the Los Angeles River to intercept larger items before they reach the shoreline.
- Beginning in February 2001, the San Diego County Board of Supervisors increased the number of county employees on road-maintenance crews that sweep streets and clean culverts as part of the county's effort to reduce water pollution from urban runoff.
- The Irvine Ranch Water District, Municipal Water District of Orange County, and National Water Research Institute are conducting a demonstration project within the City of Irvine to install landscape irrigation controllers that use satellite-provided weather information along with soil-moisture content monitoring to reduce over watering.

In addition, most coastal municipalities and counties have undertaken public-information campaigns to reduce the dumping of waste in storm drains, limit activities that contribute to street-level runoff such as landscape irrigation and car washing, and raise awareness of the meaning and importance of beach warnings.

### 6. Reality Check

The anticipated price tag for these activities is in the billions of dollars. In fact, just the Los Angeles Regional Water Quality Control Board's 12-year plan for eliminating trash in the Los Angeles River was estimated to cost $1.75-billion alone. State and federal financial support is being actively sought, and state support has been forthcoming as Governor Davis has designated a portion of the state's water bond funding for "clean beach" projects. Even with state and federal support, however, local governments throughout Southern California will face difficult budgetary tradeoffs to sustain the current level of activity or anything close to it.

There is little question that local and state officials are responding to public pressure to address the beach closure and ocean water-quality problems as well as the runoff issue that has been connected with them. The survey data clearly indicate that people are concerned about the health risks associated with going to the beach and entering the water. They believe these problems are bad and getting worse. They want something done, and even say they are willing to pay to have it done. In a democratic republic, public officials are expected to respond to these kinds of concerns.

But public pressure is itself a product of perceptions based on recent experience and information. It is fair to ask whether and to what extent the public's information — from news reports, county health officials, and the public-information campaigns of advocacy groups — about the beaches and the risks to their health compares with the available scientific research. How does what we think we know compare with what is actually known?

Indeed, as billions of dollars of public funds are devoted to additional efforts, it is only responsible to ask the following questions:

- Regarding the water-quality measures that are used in ocean testing and monitoring programs, how valid and reliable are these measures in detecting the presence of illness-causing bacteria or viruses in the ocean? Are some water-quality indicators better than others and, if so, why? What do our current water-quality testing procedures miss?

- What is known about coastal runoff and its relationship to ocean water quality? What pollutants have been found in coastal runoff? Are water-quality measures that were developed to detect sewage in ocean water appropriate for measuring the contaminants that may be carried by runoff?
- How are human health risks from ocean water contact assessed? What types and severity of illness symptoms are experienced by recreational beachgoers? How do those risks relate to the water-quality measures we use? Has prior research established statistical associations between illness symptoms and the water-quality indicators used under AB 411? What about cause-and-effect relationships? What are the strengths and weaknesses of the epidemiological studies that have been used to develop the current water-quality standards?
- What tradeoffs are involved in improving ocean water quality by controlling and reducing runoff-related pollution? Do we have measures of the benefits that would be gained in terms of reduced illnesses, fewer beach closures, etc.? How do these benefits appear relative to the costs? On the other hand, what are the costs of failing to improve ocean water quality?

This research project is premised upon the view that these are reasonable questions to ask. Subsequent chapters of this report will address them. First, we will review some of the information that has been presented to the public about runoff, ocean water quality, and health risks.

# CHAPTER TWO
# NEWS MEDIA REPORTING OF HEALTH RISKS FROM OCEAN WATER CONTACT

The public receives much of its information about ocean water conditions and the risks associated with runoff-related pollution from news reports. Media reporting sometimes employs dramatic or, at least, catchy phrasing to grab the public's attention and make stories more readable, viewable, or listenable.

## 1. Recent Media Treatment of the Ocean Water-Quality Issue in Southern California

The reporting on runoff-related risks has been no exception. Attention-catching headlines and sub-heads convey a sense of dangerous ooze and slime lurking in the waters, waiting to make people sick. Here are some examples:

> "California's Deadliest Rivermouths" ~ *Surfing* magazine, July 1996
>
> "Sea Sick?" ~ *Los Angeles Times*, June 25, 1998
>
> "When Beaches Are Sickening" ~ *Los Angeles Times*, July 11, 1999
>
> "Something In the Water" ~ *Los Angeles Times*, July 12, 1999
>
> "It's Enough to Make You Sick" ~ *Los Angeles Times*, July 12, 1999
>
> "Water Is a Zoo of Tiny, Icky Creatures" ~ *The Deseret News* (Salt Lake City, Utah), August 1, 1999
>
> "A Microscopic Zoo Puts Bathers at Risk" ~ *The Record* (Bergen County, New Jersey), August 9, 1999
>
> "Polluted Ocean Is Nothing to Sneeze at for Humans" ~ *The Orange County Register*, August 14, 1999
>
> "The Muck Stops Where?" ~ *Los Angeles Times*, September 5, 1999

Broadcast news accounts must be just as catchy to keep the viewer tuned in for the story instead of speeding away via remote control. An NBC Nightly News segment that aired July 16, 1999, opened with this sit-up-and-take-notice lead: "Polluted beaches, the water laced with disease-causing bacteria." Another NBC story on September 2, 1999, opened: "In a surprising number of communities, coastal waters are so dirty, they can be dangerous. What's going on?" The same broadcast featured a quote from Peter Green, then Mayor of Huntington Beach: "This urban runoff is a toxic witch's brew."

Below the headlines, scattered throughout the news stories, are other phrases that reinforce the image of danger cascading into the surf:

> "The next time you plan a cooling splash in the ocean ... remember you could have company that leaves you with a medical memento of your visit." *Los Angeles Times*, July 12, 1999
>
> "The polluted storm-drain runoff that sickens swimmers in Santa Monica Bay." *Los Angeles Times*, May 13, 1999

> "What flushes into the Pacific Ocean is an urban stew with disease-carrying microbes mixed in with trash." *Los Angeles Times*, September 5, 1999
>
> "The nasty soup of oil, grease, pesticides, and animal waste that washes off the nation's streets during storms, flowing into storm drains and emptying eventually into nearby rivers and bays. . . ." *The Christian Science Monitor*, September 21, 1999
>
> "Rivers of urban pollutants washing into Orange County beaches. . . ." *Orange County Register*, November 7, 1999
>
> "A toxic plume spreads far into the ocean, a threat to sea life and humans." *Los Angeles Times*, December 15, 1999

The writing may be colorful, but reporters are quick to show that they are not pulling these images out of thin air. News stories on runoff-related ocean pollution and its risks to beachgoers stake their claims on science, often in unequivocal terms. Pollutants found in ocean water and urban runoff "cause" illness or are "known" by "experts" to endanger people's health. Here are a few examples:

> "The link between storm-drain outfalls and human illness is well-established, thanks to recent epidemiological research at Santa Monica Bay." *Ventura County Star*, July 18, 1999
>
> "Though the nation's waterways aren't as dangerous as they were in 1969, when the polluted Cuyahoga River in Ohio caught fire, experts say they still seriously threaten people's health." *Los Angeles Times*, August 15, 1999
>
> "Ingestion of water contaminated with the bacteria has been known to cause severe illness and even death in some cases." *Seal Beach Sun*, August 19, 1999
>
> "Extremely high levels of *Enterococcus* known to cause gastrointestinal and respiratory infections." *Associated Press*, September 3, 1999

Is all reporting on ocean water pollution so emphatic? Of course not. It is much easier to spot and remember the catchy headlines and the images of danger (which is in no small measure why they are there). It would be incomplete, even dishonest, to show only the boldest, most attention-grabbing statements found in media accounts.

Reporters do provide more careful and nuanced explanations of what is and is not known about the risks of ocean water contact and why certain bacteria are used by regulatory agencies to make decisions about posting warnings and closing beaches. Those accounts may be fewer and farther between, but they are present. They also tend to be lengthier, and make for less snappy reading. Here are examples, some of which are from the same articles used earlier:

> "The rate at which occasional beachgoers and other bathers get sick from water they inhale or swallow is probably fairly low, although no one has gotten a handle on the precise rate." *Los Angeles Times*, July 12, 1999
>
> "Health officials post signs and close beaches when tests show that levels of biologic pollutants are unsafe. They monitor total coliform — a group of bacteria that come from soil, plants, animals and humans — as well as fecal coliform, most of which is the common gut-dweller *E. coli*, along with the ball-shaped *Enterococci*, another intestinal bug that enters the ocean through storm drains. These three 'indicator' bacteria don't often produce illness, but at sufficient concentrations they can indicate the presence of other microorganisms that can make you sick." *Los Angeles Times*, July 12, 1999

"All three bacteria point to the possible presence of organisms that can cause sickness in humans, ranging from stomachaches, nausea and diarrhea to ear, eye and throat infections.

"County health officials are required to post warnings, or close beaches, if the bacteria exceeds [sic] certain standards set by the state.

"Over the past year, health officials have started to pay especially close attention to *Enterococcus* because they've learned that it takes longer to dissipate in the ocean than coliforms. *Enterococcus* is therefore considered a better indicator of possible harmful organisms." *Orange County Register*, August 26, 1999

"Do *Enterococcus* readings change much?

"They can. On Friday, the *Enterococcus* reading was 110 off Magnolia Street at Huntington State Beach. On Saturday, the figure rose to more than 400. On Sunday it plunged to 16…

"Is it possible that *Enterococcus* levels in local waters have periodically reached high levels for decades, but we just didn't know about it?

"Yes. Biologists only began regular *Enterococcus* testing in north Orange County waters in June 1998. So they can't compare what's happening now to what happened since, say, the 1950s, when the county's population began to soar." *Orange County Register*, August 31, 1999

"How much risk of getting sick do I face if I do enter the ocean that has been posted as potentially unsafe?

"No one knows. A study has never been done in Orange County waters that clearly states how likely you are to become sick from entering the ocean where there are lots of bacteria that point to the possible presence of unhealthy organisms." *Orange County Register*, September 8, 1999

### 2. Content Analysis of Media Reporting on Health Risks and Ocean Contact

From these examples, it may be clear that we cannot develop a thorough picture of reporting on this topic (or probably any other) simply by scanning published or broadcast reports and picking out particular quotes or headlines. Almost anyone, trying to prove almost any point, could find examples to support his or her perspective.

Our project, therefore, took a different approach. Using a method known as content analysis, we attempted to characterize the reporting on ocean water quality and health risks within a particular time frame for a particular region. Through content analysis, we attempted to develop quantitative data from and about the news accounts — data that could be analyzed, compared, and presented with minimal reliance upon the subjective perception of the reader, listener, or viewer.

### 3. The Sample

The first step in conducting a content analysis is to determine the sampling frame — the time and place parameters within which the analysts will collect the records to be coded. The time parameters of our sampling frame were June 1 through December 1, 1999. This 6-month period was chosen for a combination of reasons: first, we anticipated that 6 months would provide a large, but not overwhelming, number of news reports and, second, the latter half of 1999 was the most recent 6 months before we wrote the research proposal in early 2000.

The place parameters were Southern California (from Ventura County in the north to San Diego County in the south) and Florida. These regions were chosen because of their heavily urbanized coastal character, including a great deal of beach-related tourism and other economic activity. In other words, they are regions where urban coastal runoff, ocean water quality, and swimming-associated health risk were likely to be regarded as newsworthy topics. For reasons described in Chapter 1, our primary interest was in Southern California, but we added Florida to have a body of news reports with which to compare news reporting in California.

Using these time and place parameters, we then collected news reports — print or broadcast — that covered ocean water quality and health risks. We used three techniques to collect the reports:

- A Lexis-Nexis online search using our time and place parameters and multiple combinations of search terms, such as "beach," "ocean," "pollution," "illness," "health," "warning," "closed," etc.
- "$H_2O$ in the News," the product of a news-clipping service that gathers and reprints water-related articles particularly of interest in Southern California.
- Reports saved in the individual files of the principal investigators and graduate students who worked on this project.

These collection techniques yielded 176 print articles or broadcast transcripts. Of these, 116 were from or about Southern California and the remaining 60 were from or about Florida.

We subjected each of these 176 reports to a preliminary screening to determine their relevance to our project. A report could have made it into our initial collection, yet not have been relevant to ocean water quality and health risks. For instance, combinations of search terms such as "beach"/"illness" or "pollution"/"health" could have identified an article within our time frame and location parameters, but did not have a connection to ocean water quality or ocean water contact.

The preliminary screening left 92 items in the database. Of those, 59 were from or about California and the other 33 were from or about Florida. Neither California nor Florida items were substantially more likely to have been included or rejected as a result of the preliminary screening. Of the California items, 59 of the initial 116 were retained in the database (50.9 percent). Of the Florida items, 33 of the initial 60 were retained (55.0 percent).

### 4. Coding: Collecting Data from the News Reports

To build an internally consistent set of data from this database, we established coding criteria. Those criteria identified the information that was to be recorded from each item (i.e., each article or broadcast).

The coding process then consists of a project researcher (in this case, either Principal Investigator Blomquist or one of the students assisting with the project) who read the article or transcript, marked information that matched the coding categories, and entered that information into an Excel file. In addition to coding some items himself, Principal Investigator Blomquist also reviewed every item coded by the students. An inter-coder reliability check was performed on 12 randomly selected items within the database to determine whether and to what extent different reviewers would record the information from the items in the same ways.

For each of the 92 items in the database, the following information was recorded:

- Identifying information (to place the item within the time and place parameters of the database, and to allow us to refer back to the item, if needed, after coding), including:
    a. The title of the article or broadcast segment.
    b. Date of publication or broadcast.
    c. Where it appeared (i.e., the name of the newspaper, wire service, magazine, or broadcast).

- Substantive content (capturing the information provided within the item about ocean water quality, the risk of illness from ocean water contact, and the relationship or process connecting the two), including:
    a. Whether the item referred to illness risks for human beings, marine creatures, or both.
    b. The type or types of illness mentioned (e.g., gastrointestinal, respiratory, ear infections, etc.).
    c. The source or sources of water pollution, if mentioned (e.g., sewage spills, runoff, etc.).
    d. The type or types of agent associated with illness risks (e.g., bacteria, virus, etc.).
    e. The type of connection drawn in the article or broadcast between the agent or agents and the illness risk (e.g., causation, probability, association, etc.).
- Structural content (capturing the presentation of water-related health risk information within the overall context of the item), including:
    a. Whether the item mentioned a posted beach warning.
    b. Whether the item mentioned a beach closure.
    c. Frequency — the number of times within the item that health risks were mentioned.
    d. Prominence — where the first mention of health risks appeared within the item.
    e. Proportion — the ratio of paragraphs/sentences[10] containing health risk mentions to the number of paragraphs/sentences in the entire item.

This coding structure provided the means to characterize the information presented to readers, viewers, and listeners about the health risks associated with ocean water contact in news reports from Southern California and Florida that appeared between June 1 and December 1, 1999.

## 5. Findings of the Content Analysis

After all 92 items in the database had been coded and the coding checked for completeness, we were able to determine the patterns presented by these news accounts of health risks associated with ocean water quality. The remainder of this chapter reports the findings and conclusions of that analysis. This section reports:

- The results associated with each coding category (other than the identifying information).
- How the California and Florida items in the database compared.
- Some further analysis of just the California items.

### *References to Human or Marine Health*

The references to health risks in nearly all of the articles in our database concerned human health. Seventy-five of the 92 items referred only to human health risks; one referred to marine life only, and 16 referred to both.

### *Types of Illnesses or Symptoms Associated with Ocean Water Contact*

While the majority of the 92 items in the database mentioned some type of illness, a large minority (40) did not characterize the type of illness. These articles or broadcasts referred just to “illness,” “disease,” “getting sick,” “facing a health risk,” etc. These items were coded in the illness-type category as “not indicated.”

Fifty-two of the 92 items in the database mentioned one or more types of illness or symptoms that might be associated with ocean water contact. Because an article or broadcast

10 In nearly all items in the database, paragraphs were used as the measuring units for this category. For those few items that were only one paragraph long, sentences were used instead.

could mention more than one type of illness or symptom, the numbers in the figures below sum to more than 52.

Figure 2.1 presents categories of illness types mentioned in the reports. The largest numbers of illness or symptom types mentioned are grouped in that figure as "eye/ear/respiratory" and "gastrointestinal." Those groups can be broken down to show the eye/ear/respiratory or gastrointestinal illnesses or the symptoms most often mentioned.

Figure 2.2 shows the breakdown of eye/ear/respiratory illnesses or symptoms mentioned. The abbreviation "NOI" stands for "not otherwise indicated" and was used for items that referred

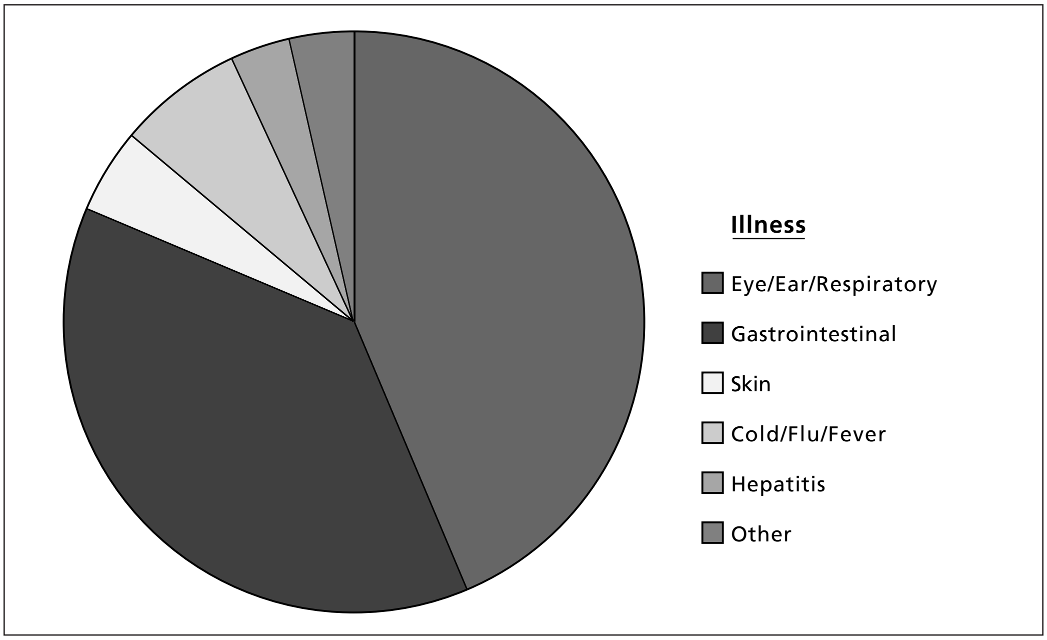


*Figure 2.1.* Type of illness mentioned.

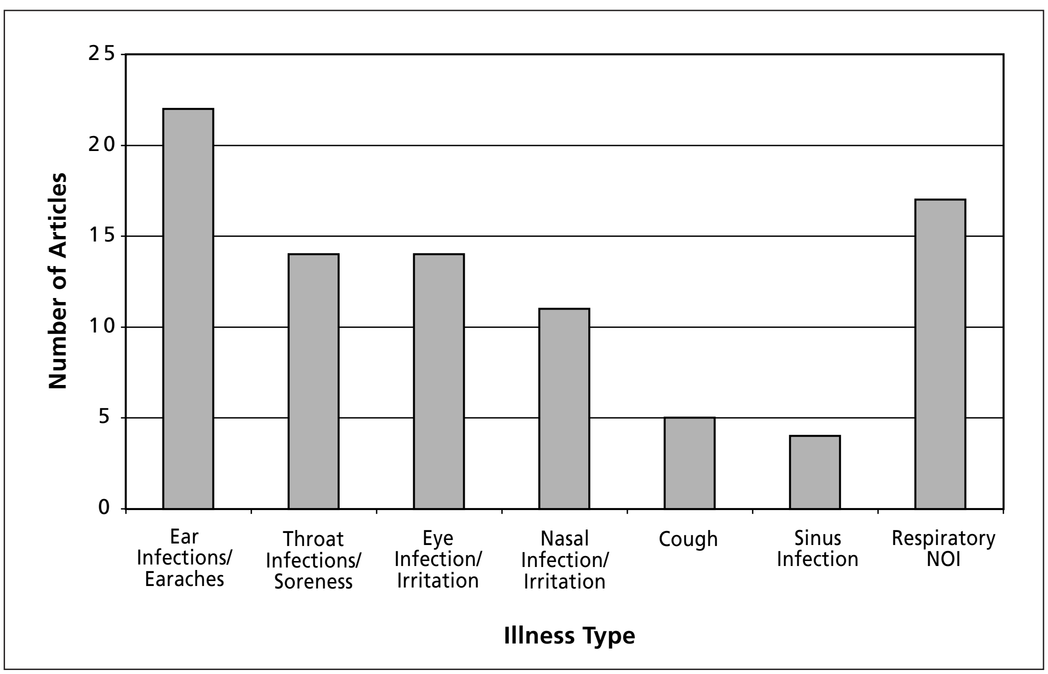


*Figure 2.2.* Breakdown of eye, ear, and respiratory illnesses mentioned. NOI = Not otherwise indicated.

simply to “respiratory” illness or symptoms, but did not specify what kind. Ear infections and earaches were the most frequently mentioned illnesses or symptoms in this group.

Figure 2.3 shows the breakdown of gastrointestinal illnesses or symptoms mentioned. Diarrhea was the most frequently mentioned illness in this group.

Figure 2.4 offers a breakdown of the other illnesses or symptoms mentioned in the news reports (i.e., those that were not in the eye/ear/respiratory or gastrointestinal groups). Skin rashes were the most common.

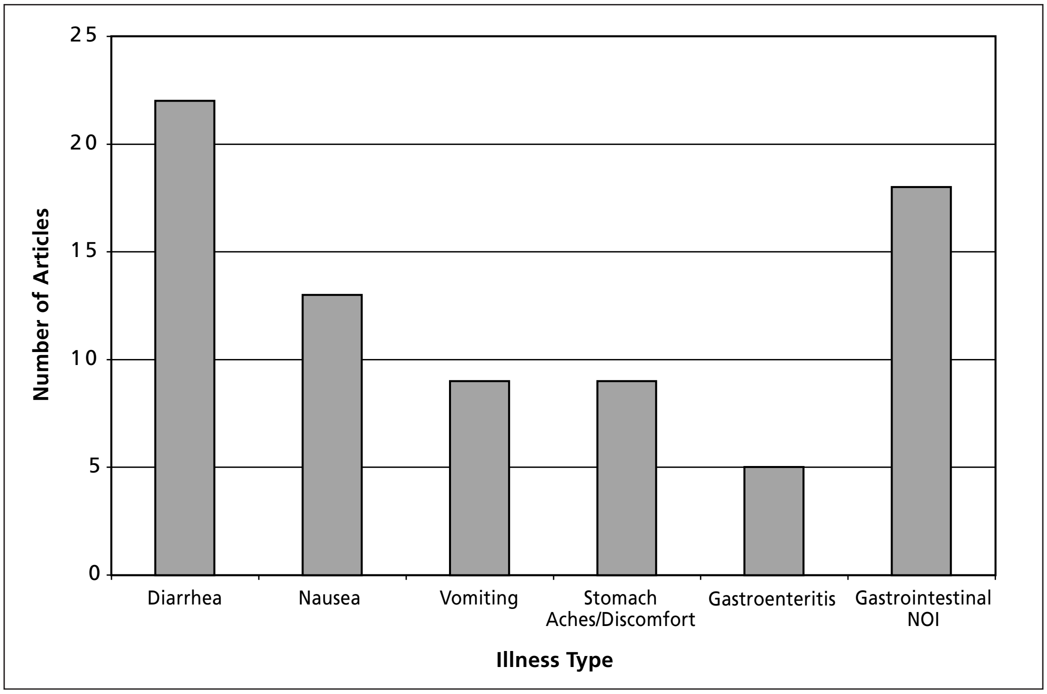


*Figure 2.3.* Breakdown of gastrointestinal illnesses mentioned. NOI = Not otherwise indicated.

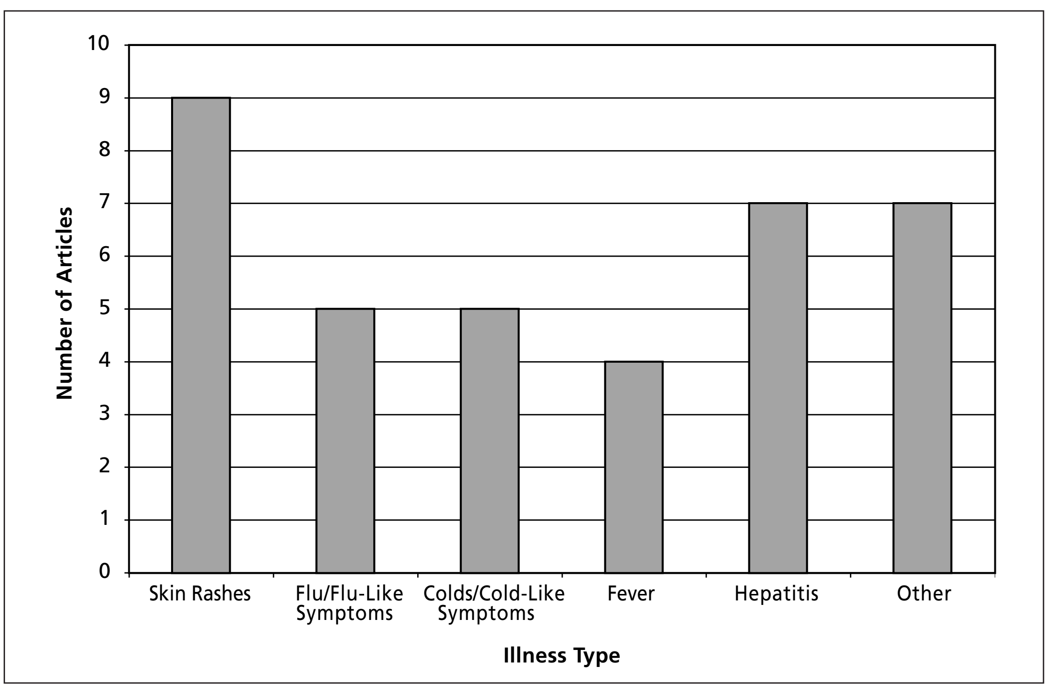


*Figure 2.4.* Breakdown of other illnesses or symptoms mentioned.

*Sources of Pollution Mentioned*

Items in the database contained references to the known or suspected source of ocean water pollution that might be associated with the illnesses or symptoms previously listed. Several articles or broadcasts mentioned more than one known or potential pollution source, so the total number of sources mentioned exceeds the number of news reports.

As Figure 2.5 illustrates, water runoff from adjacent lands was the most commonly mentioned pollution source in the items in our database. It is broken down further in

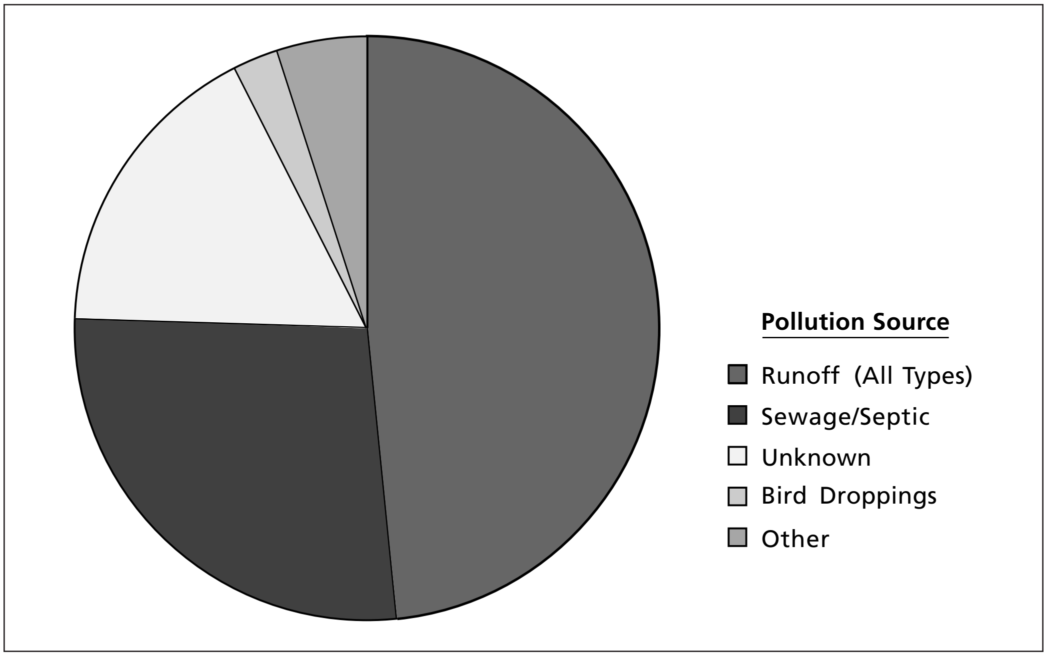


*Figure 2.5.* Pollution source categories mentioned.

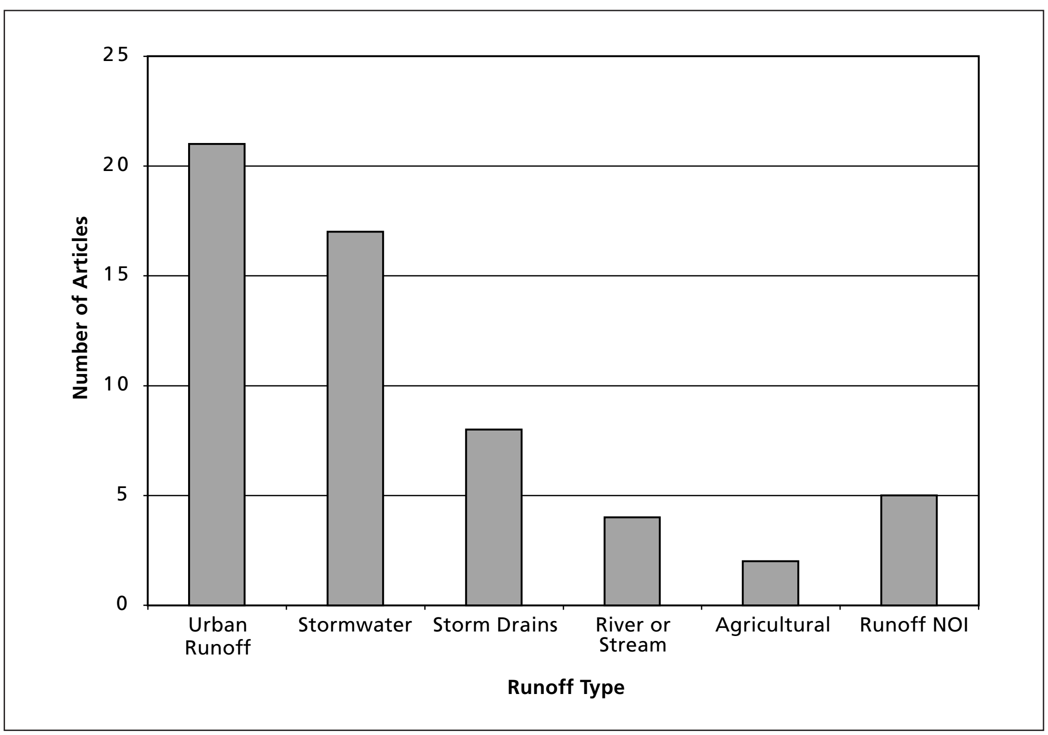


*Figure 2.6.* Types of runoff mentioned. NOI = Not otherwise indicated.

Figure 2.6, which shows the types of runoff mentioned in those articles or broadcasts. "Urban runoff" (21) and "stormwater" or "stormwater runoff" (17) were mentioned most often.

The "unknown" classification appears prominently in Figure 2.5 and combines two types of reports. In some reports, ocean water pollution was mentioned, but there was no indication of a known or potential source. Other reports actually stated that the source of pollution was not yet known. Both types of reports (20 in all) were coded as "unknown" with respect to the pollution-source category.

***Illness-Related Agents Mentioned***

When drawing a connection between impaired ocean water quality and illnesses or symptoms associated with ocean water contact, most of the news reports in our database identified one or more illness-related agents. Typically, these were one or more types of bacteria or viruses that were or might be present in ocean water.

As Figure 2.7 illustrates, bacteria were by far the most frequently identified illness-related agent. The 74 mentions of bacteria included 12 references to *Enterococci*, eight to FC, and one to *E. coli*, with the remaining 53 references only to "bacteria." Viruses in ocean water were mentioned in 12 news reports as posing potential health risks for beachgoers.

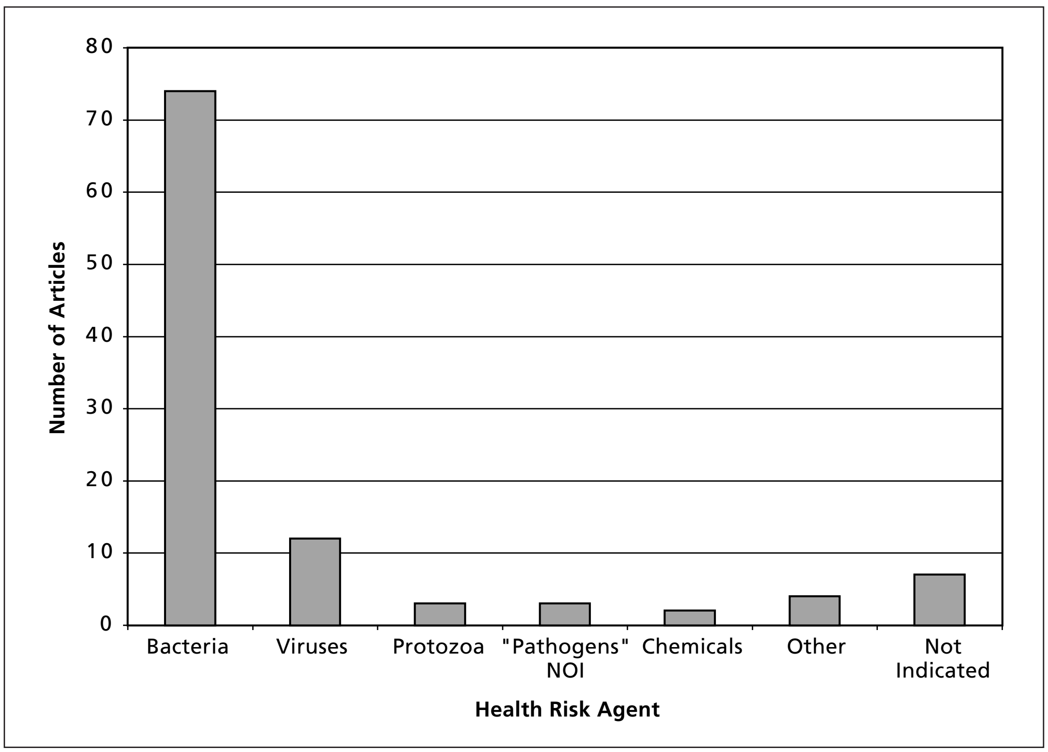


*Figure 2.7.* Health risk agent mentioned.

***Statement of Connection Between Agent and Health Risk***

In this category, we attempted to capture how each article or broadcast conveyed the relationship between a type of agent found in ocean water and the health risks associated with ocean water contact. In other words, we tried to indicate whether an article or broadcast stated or suggested a cause-and-effect relationship between exposure to the agent in ocean water and a type of illness or symptom experienced after water contact, or an association or correlation between the two, a chance or possibility, or some other connection.

Coding this category required the exercise of some interpretation or judgment by the reviewers. Most articles or broadcasts contained language that made coding this category straightforward. For instance, an expression such as “disease-causing” made it easy to code the news report as stating a causal connection, and an expression such as “might get sick” was readily coded as an expression of chance or possibility. In other cases, reviewers had to draw inferences to place the language of a news report within one of our classifications — for example, to decide what connection is implied by an article that says bacteria levels “have been linked with” increased rates of illness (which we would have coded as a statement of association or correlation).

After coding several items, we added a classification called “vague.” In some articles or broadcasts, the phrasing of the connection between ocean water contact and health risks made it virtually impossible to assign it to one of our other classifications. Examples included references to “unhealthy levels” and “safe levels” of bacteria in ocean water or to “unsafe” conditions for swimming.

An inter-coder reliability check performed on 12 of the 92 items in the database showed that reviewers agreed 11 of 12 times (92 percent) on how to code this item. Principal Investigator Blomquist read all 92 items in the database, reviewed the coding, and recoded several items for the sake of consistency.

Finally, there were a few items in the database (six of 92) that referred to degraded ocean water quality or to warnings being posted or beaches being closed to water contact, but contained no language characterizing the connection between ocean water and health risks.

Figure 2.8 shows that a majority of news reports (52 of 92) characterized the connection between health risks and exposure to pollution through ocean water contact in cause-and-effect language. The other 40 reports were scattered among other possible classifications.

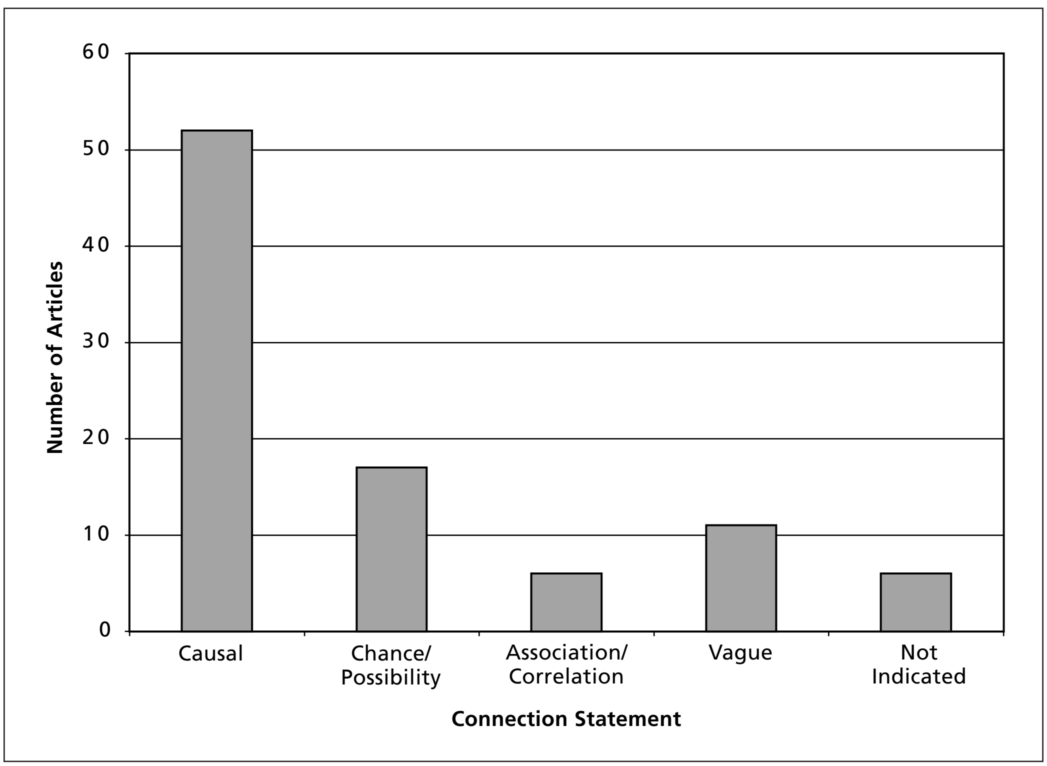


*Figure 2.8.* Types of connection statements made.

***Warnings and Closures Mentioned***

We attempted to record whether and to what extent news reports mentioning health risks associated with ocean water contact appeared in connection with a particular event, such as the posted warnings at a beach or beach closures. We did not attempt to characterize any connection drawn in the news reports between the health risks and the warnings or closures; we simply coded as "yes" or "no" whether the report contained a reference to a beach warning or closure.

Forty-three of the 92 items in the database included mention of warnings being posted or remaining in effect. Fifty-six of the 92 items included mention of beach closures. These numbers sum to more than 92 because some reports mentioned both warnings and closures.

***Number of References Per News Report to Human Health Risks***

In each article or broadcast, we counted the number of statements made about human health risks in connection with ocean water contact or quality. The findings were as follows:

*Range:* Zero to 10 mentions of health risks per item.
*Median:* 1.5 mentions.
*Mode:* One mention (44 of 92 items).

Thus, while one article contained as many as 10 references to health risks, the most common number (mode) of health-risk mentions per news report was one. The median of 1.5 simply means that half of the 92 news reports in our database contained one or zero health-risk references and the other half contained two or more references.

***Prominence of Health Risks Within News Reports***

In each article or broadcast, we recorded where in the item the first reference to human health risks appeared. In other words, we attempted to capture "how high up" in the story some reference to health risks from ocean water contact appeared. Here are the findings:

*Range:* From first paragraph (or sentence[11]) to twenty-eighth paragraph.
*Median:* Third paragraph or sentence.
*Mode:* First paragraph or sentence (21 of 92 items).

A pattern could not be discerned in the reports with respect to this category. The first mention of health risks could appear as high up as the first sentence of a story or as far down as the twentieth-eighth paragraph. While the opening paragraph or sentence was the most common site of the first reference to health risks, half of the news reports in our database did not mention health risks until after the third paragraph or sentence.

***Proportion of the News Report Devoted to Health Risks***

Finally, again using paragraphs (or sentences in single-paragraph reports) as our measure, we attempted to capture what proportion of each news report in our database dealt with health risks associated with ocean water contact. Here are the findings:

*Range:* From 0.03 or 3 percent of the story (1 paragraph out of 29) to 1.00 or 100 percent of the story (in a single-sentence report).
*Median:* 0.11 or 11 percent of the story (equivalent to one paragraph or sentence in a 9-paragraph or 9-sentence story).
*Mode:* 0.08 or 8 percent of story (seven of 92 items had this proportion).

About one in 12 paragraphs of a news report contained some reference to health risks, and the proportion was less than one in nine in more than half of the stories.

11 As mentioned in Footnote 1, sentences rather than paragraphs were counted where an article or broadcast was only one paragraph long.

*Comparing the California and Florida Coverage*

The findings above revolve around the 92 items in our database, with the California and Florida items combined. We also separately analyzed 59 articles or broadcasts from or about California and 33 articles or broadcasts from or about Florida to see whether there were any notable differences between the coverage of these topics between the two regions. Some of the coded categories are illustrated in Figure 2.9.

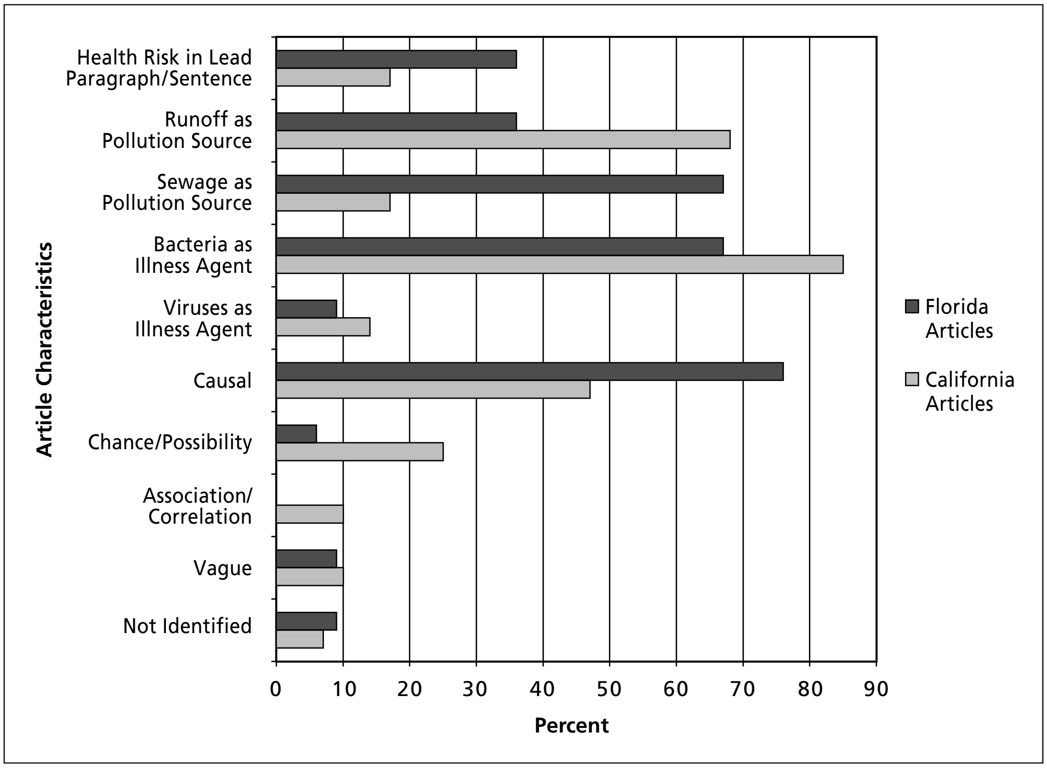


*Figure 2.9.* Comparing Florida and California items.

In stories connecting recreational water contact with human health risks, Florida news reports were more likely to feature health risk statements in the lead paragraph or sentence. Twelve of the 33 Florida reports (36 percent) in our database featured the health-risk topic prominently, compared with 10 of the 59 California reports (17 percent).

There was a large difference in the identification of ocean water pollution sources. Two-thirds of the California articles (40 of 59, or 68 percent) mentioned runoff as a pollution source, while two-thirds of the Florida articles (22 of 33, or 67 percent) mentioned sewage.

In news reports of both regions, bacteria were by far the most often mentioned illness-related agent associated with ocean water contact. Bacteria were mentioned in 67 percent of the Florida articles and 85 percent of the California articles. Viruses were mentioned in 14 percent of the California reports (8 of 59) and 9 percent of the Florida reports (3 of 33).

In the connections drawn between those agents and human health risks, notable differences reappeared. Causal connection statements appeared in three-quarters of the Florida reports (76 percent), compared with just under half (47 percent) of California reports. California news items were more likely to use language conveying a chance or possibility of illness (25 percent of the items) compared with 6 percent for Florida.

***Further Analyses of the California Items***

The 59 news reports from or about Southern California were further analyzed to search for any other patterns relating to the health risk claims made about ocean water contact.

Figure 2.10 shows that the California news reports were more likely to make causal claims about health risks from ocean water contact when sewage was the reported pollution source, compared with runoff as a pollution source. All seven of the California reports that identified sewage as the known or potential pollution source stated the connection to illness risk in cause-and-effect terms.

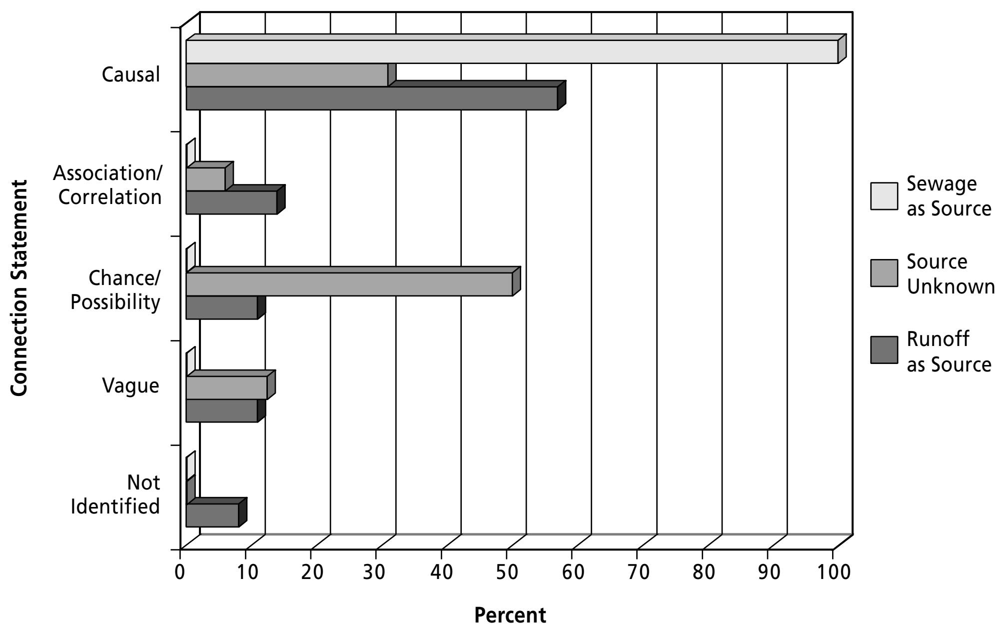


*Figure 2.10.* Connection statements (California items only).

By contrast, there were 37 California articles or broadcasts that mentioned runoff as a pollution source. Of these 37 reports, 21 (57 percent) made causal claims, 5 (14 percent) made claims of association or correlation, 4 (11 percent) made statements of chance or possibility, another 4 (11 percent) made statements too vague to classify, and 3 reports (8 percent) did not state the health-risk connection.

California reports were least likely to include causal statement when the source of the pollution was unknown or no source was mentioned. Of those 16 news reports, eight (50 percent) used language of chance or possibility and five (31 percent) included causal statements.

We also analyzed the California reports according to whether viruses or bacteria were mentioned as the illness-related agents associated with ocean water pollution. These findings are portrayed in Figure 2.11.

Causal statements appeared in nearly all (87.5 percent) of the eight California reports that mentioned viruses. Causal statements appeared in less than half (44 percent) of the 48 California items that mentioned bacteria as the illness-related agent. Statements of chance or possibility appeared in 27 percent of the reports, statements of association or correlation in another 10 percent, and statements too vague to classify in 12.5 percent.

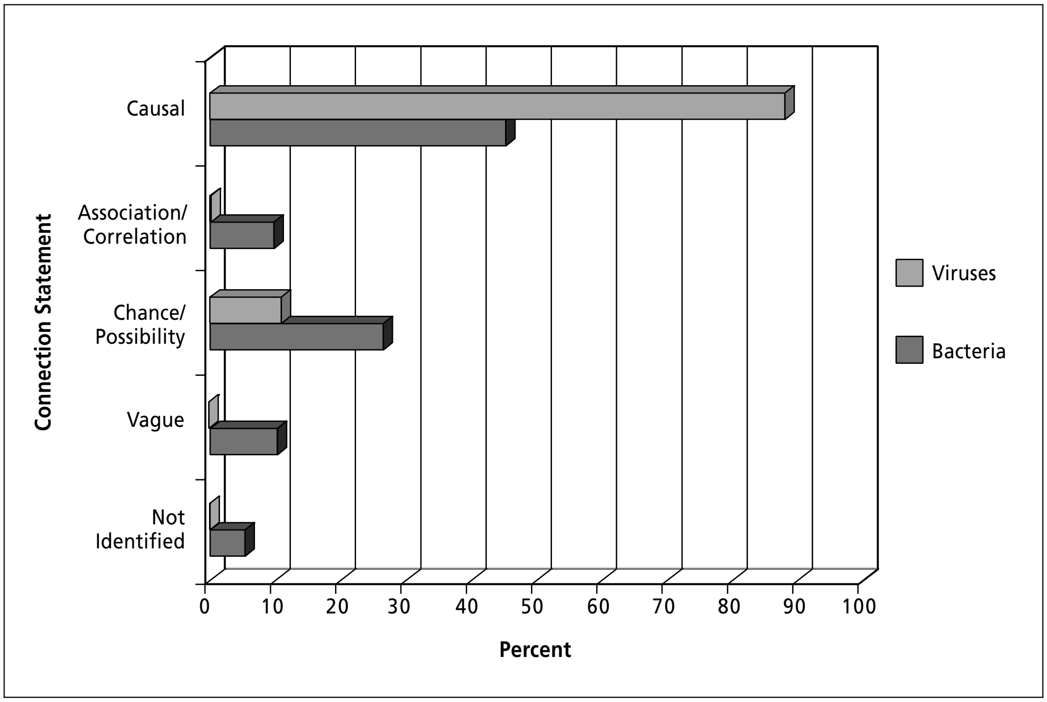


*Figure 2.11.* Connection statements (California items only, continued).

### 6. Conclusions from the Content Analysis

Most of the news reports in our database did not distinguish between indicator organisms, which are used for ocean water-quality monitoring, and actual pathogens. Instead, those news reports drew direct connections between high indicator counts and human health risks. Subsequent chapters of this report will summarize published scientific research on the microbial indicators of ocean water quality, their association with organisms that are pathogenic to people, and the relationship between exposure to ocean water with high indicator counts and the frequency of illness.

The connections between human health effects and coastal water quality were most often stated in cause-and-effect terms. The frequent appearance and repetition of causal statements in the news reports were arguably beyond what can be supported or sustained from the published scientific research literature.

Reports mentioning viruses in ocean water were more likely to include causal statements about health risks from exposure than reports mentioning bacteria in ocean water. This was true of the California items alone and of the California and Florida items combined.

News reports from or about Southern California were less likely to feature health risk claims more prominently or to devote more space to health risk statements than reports from or about Florida. News reports from or about Southern California were also less likely to state causal connections between ocean water quality and human health risks than reports from or about Florida.

California media reports most often stated causal connections about ocean water quality and human health risks when sewage was mentioned as the pollution source. Causal connections were less often drawn when runoff was the pollution source, and still less often when the pollution source was unknown.

# CHAPTER THREE
# COMMUNICATING HEALTH RISKS: THE HEAL THE BAY BEACH REPORT CARD

One of the most significant, well-publicized sources of information about beach water quality in Southern California is an annual beach report card published by Heal the Bay, a Los Angeles-based environmental advocacy group. Now in its twelfth year, the beach report card is released each May for the preceding April-to-March period. It grades the dry and wet season water quality of all beaches from Santa Barbara to San Diego:

> Heal the Bay's [beach report card] provides essential water quality information to the millions of people who swim, surf, or dive in Southern California coastal waters. Essential reading for ocean users, the report card grades over 250 locations on an A-F scale based on the risk of adverse health effects to humans. The grades are based on daily and weekly bacterial pollution levels in the surf zone (Heal the Bay, 2000a).

In its May 2000 beach report card, for example, Heal the Bay reported that 66 percent of all Southern California beaches received an "A" for dry-season water quality during 1999 to 2000, but 62 percent received "F" grades during rainy periods (Heal the Bay, 2000a).

The beach report card is widely used as a means of evaluating beach safety by print and broadcast media, and even by public officials (e.g., Los Angeles County Grand Jury, 2000). Each year's beach report card release stimulates feature stories about regional water quality. More than 20 major national and regional news stories, as well as blanket local television coverage, followed the May 2000 beach report card release. For instance, drawing on the May 2000 beach report card data, the *Associated Press* ran a story titled, "California Coast Is Where Bacteria Meets The Beach." The article stated, "There are no data on how many people fall ill by swimming at polluted beaches, but it is common knowledge among surfers that nasal, throat, and ear infections are no fluke." It quoted a San Diego surfer's opinion that, "It's getting like surfing in a toilet." Heal the Bay's Executive Director, Marc Gold, stated, "I wish I could say that things are getting better, but I can't" (D. Williams, 2000).

Under a headline announcing "More Bad News For Beachgoers," *The Los Angeles Times* ran a post-beach report card article stating, "Beaches … are clean and inviting when the weather is dry, nasty and sickening when the weather is wet … Potential health risks vary depending on exposure, but can include stomach flu, ear infection, upper respiratory infection, and major skin rash." It quoted Heal the Bay's Gold as saying, "What [the beach report card] tells us is that we have a major stormwater pollution problem. We're not doing what we need to make these beaches clean" (Morin and Mehta, 2000).

The *Daily Bruin,* the student-run newspaper of the University of California, Los Angeles, also ran a feature article that began by suggesting, "Judging by statistics, the coasts of the City of Angels may seem more like hell than heaven to visitors." The article further contended, "The Santa Monica Bay has been polluted with higher levels of contaminants than waters of any other urban area in the United States." Observing that the region has "300,000 surfers," the *Daily Bruin* expressed concern about the "startling facts" that "Los Angeles waters have also been known to carry dangerously high levels of parasitic protozoal spores, and viruses such as Hepatitis A" (Porter, 2000).

Very few, if any, media reports or public discussions of the annual beach report card releases, however, even briefly examine the underlying information and methods used to compile the beach water-quality rankings. The beach report card relies exclusively on water sample analyses of coliform and *Enterococci* concentrations over time. As such, it is prone to the same problems (as discussed in Chapter 4) affecting any health risk assessment regime that uses such secondary indicators of actual disease-causing agents. These concerns are magnified in many instances, though, by the calculation and data adjustment methodology that Heal the Bay employs to derive its beach rankings.

### 1. The Beach Report Card Methodology

The beach report card is based on the single-sample bacterial concentration standards established by California Health and Safety Code §115880 et seq. for the implementation of AB 411, which required the California Department of Health Services to set "protective minimum standards for total coliform, fecal coliform, and *Enterococci* bacteria" concentrations found in beach water grab samples taken at various locations along the California coast. The current standards include single sample limits, expressed as maximum allowable numbers of organisms per 100-milliliter (mL) sample, and maximum 30-day log mean limits for each coliform and *Enterococcus* indicator (Table 3.1)

*Table 3.1* AB 411 Single Sample and 30-Day Log Mean Standards

| Indicator | Single Sample Standard | 30-Day Log Mean Standard |
|---|---|---|
| Total Coliform | 10,000 Organisms/100 mL | 1,000 Organisms/100 mL |
| Fecal Coliform | 400 Organisms/100 mL | 200 Organisms/100 mL |
| Enterococci Bacteria | 104 Organisms/100 mL | 35 Organisms/100 mL |
| Ratio of Fecal Coliform to Total Coliform when Total Coliform Exceeds 1,000 Organisms/100 mL | 0.1 | Not Applicable |

The AB 411 implementing regulations added a fourth standard that measures the ratio of FC-to-TC when TC counts exceed 1,000 organisms per 100-mL sample. The intent of this standard, according to the California Department of Health Services, is to measure and protect against circumstances in which the total number of coliforms rises above a minimum threshold and the proportion of FCs in that total is relatively high.[12]

Heal the Bay's methodology starts with California's single sample bacteriological standards, but then substantially modifies them. The beach report card divides the FC, TC, and *Enterococci* of AB 411 standards into four "risk" ranges (Table 3.2):

12 The Department's Statement of Reasons for the AB 411 implementing standards indicates that the FC-to-TC ratio was derived from unpublished recalculations of the Santa Monica Bay Epidemiological Study's results. See California Department of Health Services, AB 411 Implementing Regulations Statement of Reasons, Section 7958, Bacteriological Standards. The California Department of Health Services' comments to AB 411's implementing regulations also note that the ratio was expressed in the study in terms of TC-to-FC ratios, but that the Department elected to use the inverse of this measure. The beach report card uses the study's TC-to-FC ratio rather than the California Department of Health Services' approach.

- The AB 411 standards *minus* a single standard deviation of expected laboratory testing variability.
- The AB 411 standards *plus* a single standard deviation of expected laboratory testing variability.
- More than the AB 411 standards *plus* a single standard deviation of expected laboratory testing variability.
- Conditions in which the ratio of TC-to-FC exceeds 2.1 when TC samples are in excess of 1,000 organisms per 100 mL.

*Table 3.2* Beach Report Card Risk Assessment Categories

| Indicator | AB 411 Standard *Minus* 1 Standard Deviation | AB 411 Standard *Plus* 1 Standard Deviation | Greater than AB 411 Standard *Plus* 1 Standard Deviation | Very High Risk |
|---|---|---|---|---|
| Total Coliform | 6,711 to 9,999 Organisms/100 mL | 10,000 to 14,900 Organisms/100 mL | More than 14,900 Organisms/100 mL | NA |
| Fecal Coliform | 268 to 399 Organisms/100 mL | 400 to 596 Organisms/100 mL | More than 596 Organisms/100 mL | NA |
| Enterococci Bacteria | 70 to 103 Organisms/100 mL | 104 to 155 Organisms/100 mL | More than 155 Organisms/100 mL | NA |
| Ratio of Total Coliform to Fecal Coliform when Total Coliform Exceeds 1,000 Organisms/100 mL | 10.1 to 13 | 7.1 to 10 | 2.1 to 7.1 | More than 2.1 |

NA = Not applicable.

To generate its beach rankings, Heal the Bay assigns a "minus" score to each category of sample data. Six (6) points, for example, are deducted in the event a single sample exceeds the AB 411 FC, TC, or *Enterococci* limits *minus* one standard deviation. Eighteen (18) points are deducted if such samples exceed the AB 411 limit *plus* one standard deviation. TC-to-FC ratios are more heavily weighed in each risk category. Table 3.3 summarizes the "minus" point scoring system that the beach report card assigns to each risk assessment category.

*Table 3.3* Minus Points Assigned to Each Beach Report Card Data Category

| Indicator | AB 411 Standard *Minus* 1 Standard Deviation | AB 411 Standard *Plus* 1 Standard Deviation | Greater than AB 411 Standard *Plus* 1 Standard Deviation | Very High Risk |
|---|---|---|---|---|
| Total Coliform | 6 | 12 | 18 | NA |
| Fecal Coliform | 6 | 12 | 18 | NA |
| Enterococci Bacteria | 706 | 12 | 18 | NA |
| Ratio of Total Coliform to Fecal Coliform when Total Coliform Exceeds 1,000 Organisms/100 mL | 7 | 14 | 35 | 42 |

NA = Not applicable.

Once the available sampling data for each beach location is categorized, the beach report card uses the following methodology to assess health risks:

- Separate "wet" and "dry" period sampling data (based on rainfall records).
- Calculate the total gross "minus" points attributed to each sampling location on a rolling 28-day (4-week) basis, leaving the results of the first 3 weeks unadjusted and multiplying the results of the last week by a factor of 1.5.
- Divide the total number of samples per 28-day period by 4.
- Divide the total gross "minus" points by the resulting fraction to obtain the "net" minus points.
- Subtract the result from 100.
- Assign an "A+" rank to beaches with scores of 100, "A" to scores of 90 to 99, "B" to scores of 80 to 89, "C" to scores of 70 to 79, "D" to scores of 60 to 69, and "F" to scores of 59 or below.[13]

Table 3.4 illustrates this methodology with 4-week data from a hypothetical coastal sampling location. In Week 1 of this illustration, the TC count exceeds the AB 411 *plus* one standard deviation criterion, generating a minus point score of 18. FC were below any beach report card risk category measure. The *Enterococci* level did not reach the actual AB 411 standard, but still surpassed Heal the Bay's limit of the AB 411 standard *minus* one standard deviation and, therefore, generated 6 minus points. The gross minus score for Week 1 is 24.

*Table 3.4* Illustration of Beach Report Card Scoring Methodology

| | **Week 1** | **Week 2** | **Week 3** | **Week 4** |
|---|---|---|---|---|
| Total Coliform | 15,000 | 500 | 1,200 | 550 |
| Fecal Coliform | 230 | 299 | 120 | 240 |
| Enterococci Bacteria | 96 | 50 | 10 | 71 |
| Ratio of Total to Fecal Coliforms when Total Coliforms Exceeds 1,000 Organisms/100 mL | 7 | 14 | 35 | 42 |
| **Weekly Minus Points Raw Score** | | | | |
| Total Coliform | 18 | 0 | 0 | 0 |
| Fecal Coliform | 0 | 6 | 0 | 0 |
| Enterococci Bacteria | 6 | 0 | 0 | 6 |
| Ratio of Total to Fecal Coliforms when Total Coliforms Exceeds 1,000 Organisms/100 mL | 0 | 0 | 14 | 0 |
| **Weekly Minus Points (Week 4 Times 1.5)** | **24** | **6** | **14** | **9** |
| Total Gross Minus Points | 53 | | | |
| Total Samples/28-Day Period | 4 | | | |
| Total Samples/4 | 1 | | | |
| Net Minus Points | 53 | | | |
| 100-Net Minus Points | 47 | | | |
| Beach Score | 47 | | | |
| Beach Grade | F | | | |

13 Heal the Bay (2000a), pages 35 to 36.

In Week 2, only FC exceeds any of the Heal the Bay criteria. Because the FC concentration exceeds the beach report card's level of the AB 411 standard *minus* one standard deviation, Week 2 earns 6 gross minus points.

There were no FC, TC, or *Enterococci* exceedances during Week 3; however, because the TC count exceeds 1,000 organisms per 100 mL, the TC-to-FC ratio comes into play. In this case, the ratio is 10 to 1 (1,200 TC to 120 FC per 100 mL). Under the Heal the Bay criteria, this result is assigned a gross *minus* point score of 14.

In Week 4, *Enterococci* levels exceed the AB 411 *minus* one standard deviation limit, generating a minus score of 6. Because Heal the Bay adjusts the last week's score of each 4-week period by a factor of 1.5, the number of minus points actually used for Week 4 is 9.

The total minus points for the 28-day period illustrated in Table 3.4 is 53. This gross score is subject to one further adjustment — division by the ratio of the total number of samples taken to the number of weeks in the period. In the illustration, the beach was subject to four samples in 4 weeks, a ratio of 1; therefore, the net minus points total is 53 (53 divided by 1).

Subtracting this total from 100 generates a beach score of 47. This result is well below Heal the Bay's cutoff score for an "F" grade and, thus, under the beach report card ranking criteria, the beach would be considered one of the region's most dangerous health risks, even though only one indicator (TC) in one of four samples exceeded the state's AB 411 limits for recreational water quality.

## 2. Problems with the Beach Report Card Approach

The beach report card's methodology incorporates and, in some ways, exacerbates chronic problems with using bacteriological indicators to assess beach health risks. As discussed more thoroughly in Chapter 4, beach sampling regimes that rely on coliform or *Enterococci* concentrations as a proxy for disease-causing agents can over- or under-estimate actual health risks. Since the beach report card's method exclusively relies on these same water-quality measures, it is unavoidably subject to the same concerns that are discussed in the next chapter.

There are additional problems, however, with the manipulation of the water-quality sampling data that is part of the beach report card methodology. As disseminated to the public, the beach report card presents assessments of beach health risks along a relatively unambiguous A-to-F grading scale. More careful consideration, however, suggests several areas in which these assessments should be viewed with caution. The most significant considerations include the following:

### *Adjusting for Under-Reported Versus Over-Reported Data*

Heal the Bay's scoring method adjusts the applicable public health risk thresholds downward by approximately 33 percent in case of the AB 411 single sample thresholds for TC, FC, and *Enterococci*, and by 30 percent for the TC-to-FC ratio (Table 3.5). These adjustments are supposed to compensate for the chance that, due to equipment, personnel, or other factors, a sampling analysis laboratory may erroneously report the actual concentrations of indicator organisms:

> The magnitude of the water-quality threshold exceedance and laboratory variability was addressed by the inclusion of standard deviations in setting the thresholds. The standard deviations used were developed during the 1998 laboratory inter-calibration study led by the Southern California Coastal Water Research Project that involved over 20-shoreline water-quality monitoring agencies in Southern California (Heal the Bay, 2000a)

*Table 3.5* Beach Report Card Downward Threshold Adjustments of AB 411 Health Risk Standards

| Indicator | AB 411 Single Sample Standard | Beach Report Card Action Threshold | Percent Beach Report Card Reduction of AB 411 Standard |
|---|---|---|---|
| Total Coliform | 10,000 Organisms/100 mL | 6,711 Organisms/100 mL | –33 percent |
| Fecal Coliform | 400 Organisms/100 mL | 268 Organisms/100 mL | –33 percent |
| Enterococci Bacteria | 104 Organisms/100 mL | 70 Organisms/100 mL | –33 percent |
| Ratio of Total Coliform to Fecal Coliform when Total Coliform Exceeds 1,000 Organisms/100 mL | 0.1 | Not Applicable | –30 percent |

Suppose, for example, police radar guns having a standard deviation of 33 percent are used to monitor an area with a 65 mile per hour (mph) speed limit. If the variability of radar guns were comparable, the results could either misread the speed of a motorist traveling at 44 mph as 65 mph or mistakenly report a motorist traveling at 86 mph as being within the posted speed limit.

Heal the Bay's approach reduces the water-quality action thresholds far below those mandated by law to address potential *under-reporting* of sample concentrations, but does nothing to compensate for possible *over-reporting* errors. The group's concern only with under-reporting errors is analogous to having the police ticket motorists driving above 44 mph on the assumption that the radar gun data was under-reporting speeds by as much as 33 percent, while making no allowance for the possibility that a driver clocked at 85 mph might actually have been obeying the law.

To say the least, this "correction" in only one direction tends to generate data that overstate the magnitude of beach water-quality problems. Given its unilateral under-reporting adjustments, the beach report card will over time overestimate beach health risks. As our hypothetical example demonstrated, the beach report card scoring system can, in fact, rank a beach where few or no water samples actually exceed any applicable public health standards as a major public health problem.

A further illustration of the difficulties latent in the beach report card's under-reporting adjustment is shown in Table 3.6. In this example, none of the sample concentration reports exceeds the applicable AB 411 standards, including the 30-day log mean limits (which the beach report card does not use and which are lower than the single-sample standards).[14]

With its adjusted thresholds, Heal the Bay treats all sampling data as if it under-reported indicator organisms by 33 percent. As shown, many of the results in Table 3.6 exceed the beach report card's threshold of the AB 411 standard *minus* one standard deviation even though they were within regulatory compliance. In effect, minus points are assigned based on those data as if they exceeded the AB 411 limits. The result is that the beach illustrated in that table would earn an "F" ranking even though no samples exceeded any standards.

Conversely, the beach report card does not account for possible over-reporting errors (nor are there any "plus points" to account for over-reported indicator concentrations). The calibration studies on which Heal the Bay relies suggest that laboratory errors might inflate the true organism concentrations in beach samples by as much as 33 percent. Not only is this possibility not accounted for in the beach report card methodology, these incorrectly inflated

14 The California Department of Health Services does not require beach posting for 30-day log mean standard violation as is required for single sample exceedances. The regulations instead direct local officials to consider whether beaches should be closed or otherwise subjected to limited use in the event of a 30-day log mean exceedance.

*Table 3.6* Illustration of Beach Report Risk Over-Reporting

| Indicator | Week 1 | Week 2 | Week 3 | Week 4 | 30-Day Log Mean | AB 411 Standard |
|---|---|---|---|---|---|---|
| Total Coliform | 6,800 | 950 | 120 | 1,050 | 950 | 1,000 |
| Fecal Coliform | 300 | 270 | 40 | 85 | 129 | 250 |
| Enterococci Bacteria | 10 | 71 | 10 | 73 | 27 | 35 |
| Ratio of Total to Fecal Coliforms when Total Coliforms Exceeds 1,000 Organisms/100 mL | 23 | 0 | 0 | 12 | | |
| **Weekly Minus Points Raw Score** | | | | | | |
| Total Coliform | 6 | 0 | 0 | 0 | | |
| Fecal Coliform | 6 | 6 | 0 | 0 | | |
| Enterococci Bacteria | 0 | 6 | 0 | 6 | | |
| Ratio of Total to Fecal Coliforms when Total Coliforms Exceeds 1,000 Organisms/100 mL | 0 | 0 | 0 | 17 | | |
| **Weekly Minus Points (Week 4 Times 1.5)** | **12** | **12** | **0** | **19.5** | | |
| Total Gross Minus Points | 43.5 | | | | | |
| Total Samples/28-Day Period | 4.0 | | | | | |
| Total Samples/4 | 1.0 | | | | | |
| Net Minus Points | 43.5 | | | | | |
| 100-Net Minus Points | 56.5 | | | | | |
| Beach Score | 56.5 | | | | | |
| Beach Grade | F | | | | | |

reports become even more likely to meet or exceed Heal the Bay's minimum scoring threshold (the AB 411 standards *minus* one standard deviation), which means the affected beach will receive a very low, but unjustified, beach report card ranking.

Heal the Bay's approach appears to over-compensate for possible under-reporting errors in indicator concentrations in water samples, but ignores possible over-reporting errors. As a result, the beach report card results tend to substantially overestimate actual beach health safety risks, and a beach subject to only a few of Heal the Bay's below standard "exceedances" can earn the lowest possible grade on the beach report card.

Assuming it is desirable or reasonable to incorporate some measure of possible laboratory testing error into the beach report card, there are a variety of ways to score the associated health risks. Instead of 6 minus points for a sample result that fell within one standard deviation below the AB 411 standard, for example, the beach report card could assign 1 minus point. Table 3.7 applies this approach to the same data as in Table 3.6, where the beach that had no actual exceedances of any health standard receives a grade of B rather than F.

***Step-Level Jumps in Risk Scores***

The findings of epidemiological studies on whether and how bacteriological indicator concentrations (e.g., coliforms and *Enterococci*) are associated with health risks from recreational

*Table 3.7* Illustration of Revised Beach Report Card Scoring: Assigning 1 Point Instead of 6 Points to Exceedances of AB 411 Standards *Minus* One Standard Deviation

| **Indicator** | **Week 1** | **Week 2** | **Week 3** | **Week 4** | **30-Day Log Mean** | **AB 411 Standard** |
|---|---|---|---|---|---|---|
| Total Coliform | 6,800 | 130 | 120 | 1,050 | 578 | 1,000 |
| Fecal Coliform | 300 | 270 | 40 | 85 | 129 | 250 |
| Enterococci Bacteria | 10 | 71 | 10 | 73 | 27 | 35 |
| Ratio of Total to Fecal Coliforms when Total Coliforms Exceeds 1,000 Organisms/100 mL | 23 | 0 | 0 | 12 | | |
| **Weekly Minus Points Raw Score** | | | | | | |
| Total Coliform | 1 | 0 | 0 | 0 | | |
| Fecal Coliform | 1 | 1 | 0 | 0 | | |
| Enterococci Bacteria | 0 | 1 | 0 | 1 | | |
| Ratio of Total to Fecal Coliforms when Total Coliforms Exceeds 1,000 Organisms/100 mL | 0 | 0 | 0 | 1 | | |
| **Weekly Minus Points (Week 4 Times 1.5)** | **12** | **2** | **0** | **3** | | |
| Total Gross Minus Points | 17 | | | | | |
| Total Samples/28-Day Period | 4 | | | | | |
| Total Samples/4 | 1 | | | | | |
| Net Minus Points | 43.5 | | | | | |
| 100-Net Minus Points | 83 | | | | | |
| Beach Score | 83 | | | | | |
| Beach Grade | B | | | | | |

water contact suggest an increasing but gradual relationship. In other words, as indicator concentrations rise, so does the frequency of certain illness symptoms among swimmers and other recreational water users.

Heal the Bay's beach report card does not reflect this incremental relationship. The beach report card's system of minus points shown in Table 3.3 involves a limited number of step-level jumps: as concentrations of TC, FC, and *Enterococci* in water samples cross certain numerical thresholds, the number of minus points jump from 0 to 6, from 6 to 12, and from 12 to 18. The step-level jumps are even more dramatic for the TC-to-FC — as that ratio crosses certain numerical thresholds, the minus points leap from 0 to 7, from 7 to 14, from 14 to 35, and from 35 to 42.

Of course, the purpose of the beach report card is to warn the public about health risks associated with beach water-quality, so one would expect there to be changes in letter grades associated with indicator concentrations that cross the thresholds of the AB 411 standards. Informing the public that water-quality at certain beaches is above or below the state standards could, and arguably should, be translated into the letter grades reported by the beach report card.

But the beach report card scoring system places step-level jumps along several thresholds of water-quality indicator concentrations, not merely at the AB 411 standards (see Table 3.3). This is a more questionable practice, and one that seems to be at variance with the scientific research underpinning the relationship between bacteriological water-quality indicators and human health risks. If epidemiological study findings suggest a relatively steady increase in health risks as indicator concentrations rise, the rationale for having step-level jumps at relatively arbitrary points along the path is not clear. To offer an example, there is nothing in the epidemiological literature that we reviewed to suggest that as TC concentrations rise by 7 percent from 14,000 organisms per 100 mL to 15,000 organisms per 100 mL, the health risks to swimmers rise by 50 percent. Yet the beach report card scoring system assigns 12 minus points to the former and 18 minus points to the latter (see Table 3.3). Most dramatic is the jump that occurs when the TC-to-FC ratio declines from 7.0 to 6.0, producing an increase in beach report card minus points from 14 to 35 — the latter figure alone being enough to drop a beach's beach report card grade to a D even if no other indicator concentration in any sample from that beach exceeded state regulatory standards.

Thus, while the epidemiological rationale for the step-level jumps in the beach report card scoring system is unclear, the effect of the jumps on beach grades is significant. The stepwise scoring system used by the beach report card exaggerates the differences in water quality among beaches; it takes marginal numerical differences from one sample to another and from one beach to another and multiplies them into minus-point differences that can easily produce an A or B at one beach and a D or F at another though the water-quality measures at both are very nearly the same.

***Indicator Covariance***

Along with its stepwise scoring system, the beach report card incorporates multiple water-quality indicators that are highly covariant (meaning that as one rises or falls, the others tend to move in the same direction). The use of multiple covariant source data in a step-wise scoring system can skew the risk analysis, especially as the data approaches a scoring milestone.

To illustrate the covariation of the indicators, we calculated the correlation coefficients for all 32 reported water-quality samples in Los Angeles County (n=1,784) from April 1999 through March 2000. The correlation between TC and FC was 0.65, between TC and *Enterococci* was 0.70, and between FC and *Enterococci* was 0.47. These figures mean that each of the three data points used to produce the Heal the Bay report is strongly and positively associated with the others. As the level of one indicator rises in a sample set, the others rise in roughly similar proportion.

This covariation among indicators, combined with the step-level jumps in the beach report card scoring system, magnifies even further what may be marginal distinctions among water-quality samples and among beaches. The results of this combined effect can be to distort information used by the public rather than to clarify it.

Table 3.8 illustrates two weekly testing results clustered around the cutoff points defined by Heal the Bay's AB 411 *minus* one standard deviation category and the next highest risk class, the AB 411 standard *plus* one standard deviation. Although the reported concentrations of indicator organisms in Table 3.8 are very similar, the beach report card scoring system weighs the results of Week 1 six times more heavily than those for Week 2.

Thus, the beach report card's stepwise scoring system, and incorporation of data from multiple indicators that are correlated with each other, can either exaggerate or conceal true health risks. Swimmers relying on the Week 2 scores in Table 3.8, for example, would not recognize that the reported concentrations of bacterial indicators are actually quite close to a much higher risk threshold. Conversely, those who may have been alarmed by the Week 1 scoring results would not be aware that the water quality in that sample actually measured at the very bottom of the applicable risk category limit. In either case, actual relative risk information is not communicated.

*Table 3.8* Illustration of Beach Report Card Covariant Scoring Anomalies

| Indicator | Week 1 | Week 2 |
|---|---|---|
| Total Coliform | 10,000 | 9,500 |
| Fecal Coliform | 400 | 260 |
| Enterococci Bacteria | 104 | 37 |
| Ratio of Total Coliforms to Fecal Coliform when Total Coliforms Exceeds 1,000 Organisms/100 mL | 25 | 37 |
| Total Coliform | 12 | 6 |
| Fecal Coliform | 12 | 0 |
| Enterococci Bacteria | 12 | 0 |
| Ratio of Total Coliforms to Fecal Coliform when Total Coliforms Exceeds 1,000 Organisms/100 mL | 0 | 0 |
| Total Minus Points | 36 | 6 |

***Weighting of the TC-to-FC Ratio***

Most of the indicators and standards used by both AB 411 and the beach report card reflect long-standing federal and state practice and scientific analysis. One indicator, however — the ratio of TC-to-FC in the beach report card or of FC-to-TC in the AB 411 standard — is much less common and its scientific support much less certain. It appears that this ratio was derived and developed into a regulatory standard largely, and perhaps entirely, from the Santa Monica Bay Epidemiological Study, including (apparently) unpublished post-research analyses of the study results.

The rationale of the California Department of Health Services for the use of the ratio states that:

> The Santa Monica Bay investigators found that the ratio of total to fecal coliforms was related to an increase in illness . . . Additional analyses of the data from the Santa Monica Bay study compared the risk of illness among swimmers in water at different total/fecal ratios and at two levels of total coliform bacteria, 5,000 per 100 mL and 1,000 per 100 mL (Haile and Witte, undated). At a total coliform count greater than 5,000 per 100 mL, a total/fecal ratio of 10 (one-tenth of the total coliforms are fecal) was related to risks of 107 to 657 per 10,000 swimmers for eight different effects (fever, eye discomfort, ear discomfort, skin rash, nausea, diarrhea, stomach pain, runny nose). At a total coliform count greater than 1,000 per 100 mL, a total/fecal ratio of 10 was related to risks of 117 to 281 per 10,000 swimmers for three different effects (chills, nausea, diarrhea). The Department incorporated the ratio of the two coliform indicator organisms into the standards to be used . . . the results of the Santa Monica Bay study showed that the ratio of total to fecal coliforms was more predictive of illness than the *Enterococcus* concentration (The California Department of Health Services, 1999).[15]

Heal the Bay explains in similar terms why its beach report card scoring method weighs the TC-to-FC ratio more heavily than each of the conventional water-quality indicators in similar

15 In both of the numerical examples given in the quote, the TC-to-FC ratio was 10 — the difference is attributed to the ratio when the TC count exceeds 1,000 organisms per 100 mL compared with the ratio when the TC count is at 1,000 or below.

terms: "Exceedance of the TC-to-FC ratio threshold leads to lower grades because exposure to water with low ratios causes an even higher incidence of a variety of adverse health effects relative to the health risk associated with other bacterial indicators" (Heal the Bay, 2000a).

As discussed in Chapter 5, the Santa Monica Bay Epidemiological Study results exhibited significant variations among the three outfall locations it examined. Aggregating these findings into a single risk assessment measure may not adequately communicate the actual risk ranges it tries to identify.

Given the ambiguities latent in the documentation that supports the standard, the heavy weight placed on the TC-to-FC ratio in the beach report card may mischaracterize the potential health risks. The ratio also can generate illogical results. Table 3.9 illustrates sample results for 2 weeks at a hypothetical beach. In Week 1, the reported concentrations of FC, TC, and *Enterococci* are quite low compared with even the most stringent Heal the Bay standards. Yet, because the TC count exceeds 1,000/100 mL, and the ratio of TC-to-FC is less than 10, the beach report card assigns 21 minus points to the beach.

*Table 3.9* Illustration of TC-to-FC Ratio Scoring Anomalies

| Indicator | Week 1 | Week 2 |
|---|---|---|
| Total Coliform | 1,003 | 4,000 |
| Fecal Coliform | 105 | 240 |
| Enterococci Bacteria | 10 | 69 |
| Ratio of Total Coliforms to Fecal Coliform when Total Coliforms Exceeds 1,000 Organisms/100 mL | 9.6 | 17 |
| Total Coliform | 0 | 0 |
| Fecal Coliform | 0 | 0 |
| Enterococci Bacteria | 0 | 0 |
| Ratio of Total Coliforms to Fecal Coliform when Total Coliforms Exceeds 1,000 Organisms/100 mL | 21 | 0 |
| Total Minus Points | 21 | 0 |

The results of Week 2 show from 2.4 to 7 times greater concentrations of indicator organisms. Assuming that such indicators are correlated with disease causing-agents, the total amount of hazardous pathogens in the water of Week 2 is much higher than in Week 1. Yet, because none of the reported results triggers any of the Heal the Bay thresholds, no minus points are assigned to the total for Week 2 while Week 1 generates 21 minus points.

Inconsistencies such as these reflect, in part, the likelihood that the ratio measurements used in the beach report card are mathematical artifacts with as yet unknown and possibly nonexistent epidemiological significance. The Santa Monica Bay Epidemiological Study noted, for example, that the cohort of swimmers in waters that exceeded lower TC-to-FC ratios (when TC were higher than 1,000 or 5,000 per 100 mL) fell as the overall coliform ratio fell.[16] These smaller number of exposures almost certainly affect the results because a single reported illness could generate a much higher relative risk when scaled over 10,000 cases.

16 Haile et al. (1996) note that, "The largest attributable numbers [of excess illnesses] were observed for the total of fecal coliforms ratio when the analyses were restricted to subjects in water where total coliforms exceeded 5,000 cfu . . . However, these stronger effects would be limited to a smaller proportion of the beach going population (those swimming in water where the total coliforms exceeded 5,000 cfu).

The California Department of Health Services has also observed that the Santa Monica Bay Epidemiological Study "found the number of cases of swimmers near storm drains increased as the ratio of TC-to-FC coliforms decreased below 10 (i.e., when FC represented a larger proportion of the TC, the risk increased)."[17] While the Santa Monica Bay Epidemiological Study findings clearly indicate that health risks rise when people swim in storm-drain effluent, it is unclear how the TC-to-FC ratio might systematically influence beachgoers in choosing swimming locations, and it is possible that this association is largely accidental.

Efforts by public health agencies and public interest groups to find a single combined indicator of bacteriological water quality are understandable and even laudable, but for such a measure to be useful, it must rest upon a scientific foundation. The rationale for the TC-to-FC coliform ratio results is as yet poorly understood, to say the least. Using this measure as the most significantly weighed component in the beach report card methodology likely increases the chance that inaccurate beach safety information is communicated to the public.

***Outfall Sampling***

As discussed in Chapter 5, the health risks to swimmers found by the Santa Monica Bay Epidemiological Study were focused in the area immediately around flowing storm drains. As distance from the flowing outfall increases, health risks diminish, probably due to decreased concentrations of disease-causing agents as the outfall effluent mixes with ocean water.

According to Heal the Bay's reports, the data used in the beach report card are in all cases obtained from water grab samples taken within 25 to 50 yards of an outfall. This can substantially overstate beach health risks. Los Angeles County, for example, contains 50 storm drains subject to AB 411 testing along a beachfront in excess of 50 miles. Thus, approximately 95 percent of the county's total linear beachfront is located more than 50 yards from either side of each storm-drain sample location. The beach report card grades are based on data collected from beach areas located within 50 yards of a storm drain, and those data are treated as if they were representative of the entire beach. In light of the diminished health risk found by the Santa Monica Bay Epidemiological Study for swimmers located away from the storm drain, Heal the Bay's sample collection practice likely overstates the real range of risks experienced by swimmers located at varying distances from the sampling location.

***Temporal Water-Quality Variations***

The beach report card addresses temporal variability in water quality by segregating wet and dry weather results. In its May 2000 report, for example, Heal the Bay states that dry weather beach water quality is typically much better than wet weather conditions (Heal the Bay, 2000a). This result is apparently due to the fact that rain events wash effluent into the ocean and boost bacteria indicator organism concentrations.

Merely separating wet from dry season data, however, may fall short of providing accurate information about the true variability of risk experienced by beachgoers from day to day or even during a single day. Consider, for example, Surfrider State Beach at the mouth of Malibu Creek, one of Heal the Bay's most chronically low-ranked beaches (a "beach bummer" in the beach report card nomenclature). The creek's upstream watershed tends to concentrate animal (especially horse) excrement and possibly septic tank leachate from homes unserved by sewer lines, all of which is washed into a lagoon immediately contiguous with the beach. Effluent further concentrates in the lagoon through additional animal and human contamination. In dry periods, releases of treated water from an upstream sewage treatment plant can cause a lagoon breach

17 California Department of Health Services' Initial Statement of Reasons for AB 411 Implementing Regulations, Section 7958, December 1999.

and allow the impounded waters to flow into the sea. In rainy periods, spills from the plant can severely pollute the creek and its receiving waters. Over the past several years, the beach report card has consistently ranked Surfrider as among the very worst beaches in California; even Surfrider's dry-weather grades range from "D" to "F" (Los Angeles County Grand Jury, 2000).

There appears to be little question that adverse water quality at Surfrider can increase health risks. The Santa Monica Bay Epidemiological Study's most robust results were achieved at that location (see Chapter 5). The beach report card's wet/dry grading dichotomy, however, can obscure the fact that even at often polluted beaches like Surfrider, water quality can be acceptable for considerable, and generally predictable, periods.

Figure 3.1 displays the reported water-quality sampling data for Surfrider compiled by the California Department of Health Services from April 1999 to March 2000. The data show that very high levels of bacteriological indicators are found during the late winter and early spring, when most rainfall events triggering actual or potential spills from upstream facilities occur. At these times, higher health risks at Surfrider correspond with the beach's low beach report card grade.

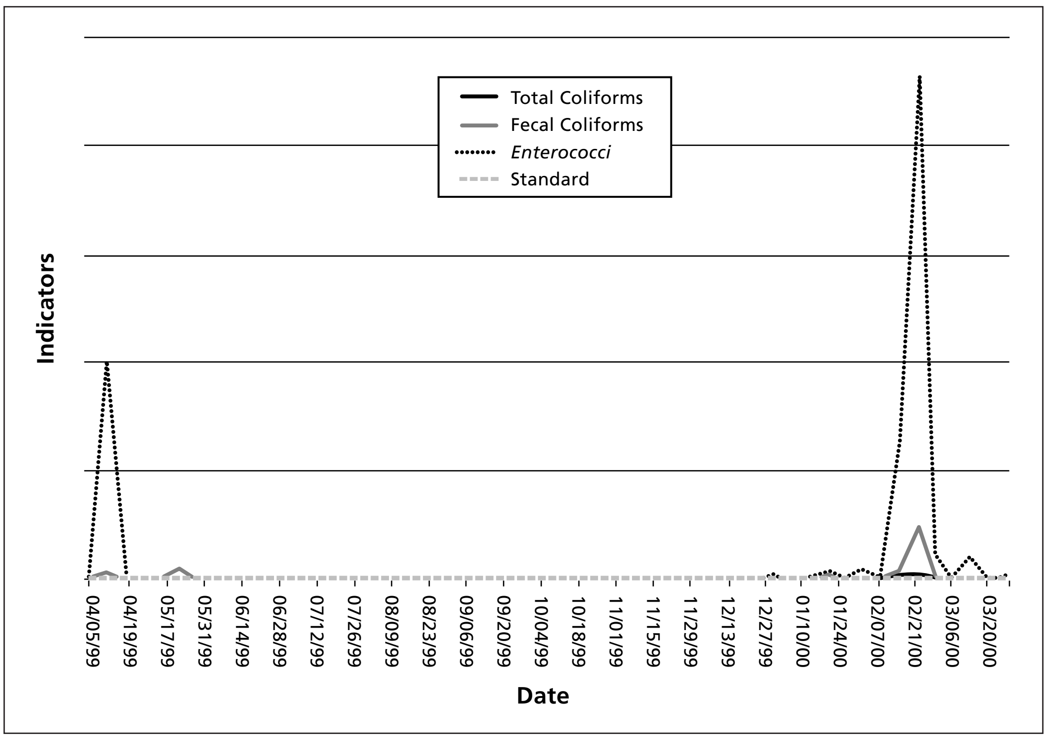


*Figure 3.1.* Relative magnitude and number of water-quality exceedances at Malibu/Surfrider Beach, April 1999 to March 2000. Source: California Department of Health Services Annual Water-Quality Sampling Result Database.

From May to December 1999, however, there were virtually no comparably significant exceedances of the AB 411 standards because dry, warmer weather reduces upstream flows and maintains the lagoon's integrity. During this period, the public heath risks at Surfrider were likely much lower, if not negligible, compared with the extremely high exceedances recorded in the late winter and early spring. This day-to-day variability is almost certainly compounded by what water-quality researchers are discovering is substantial variation during the day in response to tides, human bather intensity, and other factors (see Chapter 4).

The annual publication of the beach report card, offering only dry- and wet-season grades to represent an entire year's beach water quality, addresses temporal variability in a limited way.

Negative results are presented as if they define baseline conditions. This practice also exaggerates beach water-quality impairment. As Figure 3.1 demonstrates, even a chronically low-ranked beach may experience excellent water quality for months at a time.

Heal the Bay maintains a website (www.healthebay.com) that attempts to compile water-quality data on an ongoing basis. The information posted on that site also more heavily weighs the fourth week's data in its scoring method to emphasize current rather than historical conditions at a beach. This real-time information allows for a more nuanced communication of bacterial-indicator health risks than does an annual cumulative beach ranking. The annual beach report cards, however, are publicized by Heal the Bay's press releases and picked up in news reports throughout Southern California and the rest of the nation. Those annual grades do not communicate this information effectively.

### 3. The Beach Report Cards and Public Risk Perceptions

Despite widespread media reliance on Heal the Bay report cards in reporting on ocean water quality in Southern California, the general public does not appear to effectively absorb and accurately recall report card data. The University of Southern California's 1999 Environmental Perceptions Survey compared Heal the Bay report card grades with the perceptions of Los Angeles County residents on ocean water quality at different beaches along Santa Monica Bay (Pendleton et al., 2000).

Survey respondents were given randomly chosen pairs of Santa Monica Bay beaches[18] and asked for their opinion of which beach had the better water quality. Respondents' answers were compared with Heal the Bay report card grades. Their answers were more likely to be contrary to the Health the Bay grades than in agreement with them. One-third of the respondents (33.25 percent) identified the "wrong" beach in the pair (relative to the Heal the Bay grades) and just one-fourth (26.05 percent) identified the "right" one. The remainder did not know or were not able to venture an opinion on the beaches.

Survey respondents also did not associate storm-drain runoff with ocean water pollution problems as readily as might be assumed if the Heal the Bay public information program were having greater effect. When respondents were asked to identify the causes of ocean pollution, they most often said trash (43.18 percent) and industrial and chemical waste (41.19 percent). Raw sewage was mentioned by 29.28 percent of respondents while storm-drain runoff — the source most often publicized recently by Heal the Bay and the Santa Monica Bay Restoration Project — was fourth and last (24.07 percent) among the sources of ocean pollution identified by the respondents.

After being given the opportunity to volunteer their own opinions about pollution sources, survey respondents were then presented all four of the source categories (trash, industrial and chemical waste, raw sewage, and stormwater) and asked to rate the severity of the health risks associated with each. Respondents could state whether they thought that contact with water polluted by the source in question was likely to make a person "sick" or "very sick."

Not surprisingly, after having been prompted with the sources and having the association drawn between the sources and ocean pollution, most respondents rated all four-source categories as likely to make people sick after contact. Still, there were disparities among the source categories. Nine-tenths (90.07 percent) of respondents said contact with ocean water polluted by industrial and chemical waste was likely to make someone sick, and sewage rated

18 If a respondent was unfamiliar with one or both of the beaches in the pair, he or she was offered a second randomly chosen pair of beaches.

roughly the same (89.33 percent). Three-quarters of the respondents said that contact with water polluted from trash or storm drains (75.93 percent) was likely to make someone sick.

Larger disparities appeared over whether a pollution source was likely to make someone "very sick." The responses for industrial and chemical waste and for sewage remained above 70 percent, but the responses for trash and storm-drain runoff dropped to around 45 percent.

The University of Southern California's 1999 Environmental Perceptions Survey is only one measure of the opinions of a sample of Southern California residents and of the sources of their information. Nonetheless, the survey's findings suggest that Heal the Bay's public information program about beach water quality, and its emphasis on stormwater as the most important ocean pollution culprit of the day, are having marginal impact on area residents. Survey respondents have internalized the view that ocean water pollution is bad and getting worse, but that general perception does not differentiate among beaches or among pollution sources in ways consistent with the information provided by Heal the Bay and transmitted in news reports.

This is, of course, both good news and bad. As stated earlier, in light of the flaws in the beach report card methodology, perhaps it is just as well if Heal the Bay's identification of "beach bummers" and "beach buddies" has not been adopted by the public.

On the other hand, several years of beach report cards and news reports emphasizing the health risks associated with ocean water contact may have simply melded into a general public perception that the entire region's beaches are hell-bound and gaining speed. If so, there are at least two undesirable potential outcomes. First, some portion of Southern California residents and visitors may avoid all beaches (or, at least, water recreation while at the beach), thereby needlessly diminishing their enjoyment of one of the region's greatest public attractions and natural assets. Second, the undifferentiated perception that ocean water quality is bad and getting worse throughout the region may translate into public pressure on all local, state, and federal officials to "do something," rather than directing prevention and enforcement efforts at the areas most in need of and most amenable to improvement. If public policy responds at least in part to public opinion, there are reasons to be concerned about the effectiveness of Southern California's policy responses in light of what we are learning about news media reporting, interest group public information campaigns, and public knowledge about ocean water quality and the risks of ocean water contact.

### 4. Summary

Several aspects of Heal the Bay's beach report card methodology introduce inaccuracies in the way beach safety is graded and presented to the public. Downward adjustments to public health standards to account for laboratory inaccuracies, aggressive scoring conventions, and sampling location biases near storm drains will tend to produce overstated assessments of actual health risks. The beach report card may also either understate or overstate risks in the way it addressed daily and intra-day temporal variability in bacterial concentrations and its use of a step-function scoring system for covariant data points. Finally, the heavy weight placed on a relatively unproven and potentially logically inconsistent TC/FC factor could further generate inaccurate health risk perceptions. These problems compound the more general concerns discussed in the next chapter regarding the use of bacterial indicator proxies to predict beach safety.

# CHAPTER FOUR
# TROUBLING INDICATORS

*"Are health officials sampling for the right thing*
*and closing beaches at the proper time?*
*"The answer, experts concede, is a resounding 'no.'"*
*~ Marla Cone,*
THE LOS ANGELES TIMES,
*September 5, 1999*

Information provided to the public — through news reporting or materials such as Heal the Bay's beach report cards — about the suitability of beaches for swimming and surfing is ultimately based on some measures of water quality. This chapter discusses the measures used in California, particularly since the implementation of AB 411. Those measures are called microbial indicators of water quality.

## 1. Water-Quality Indicators and Why They Are Used

Despite news media references to beaches being closed because of "disease-causing organisms" or "disease-causing bacteria" (see Chapter 2), county environmental health officials actually base their decisions to post beach advisories on something else — a probability that the water contains such organisms, based on the presence of other bacteria that are referred to as "indicators." The distinction has been covered in news reporting,[19] but it is a subtle distinction and usually appears farther down in a news story after the initial paragraphs about a beach warning or closure being issued.

To understand the historical use of indicator bacteria, we begin with the fairly obvious question of why water quality is monitored in the first place. Water-quality testing originated due to concerns about human illnesses caused by drinking contaminated water. To put it another way, the original concern was with exposing one's stomach and intestines to pathogens and concomitant illness through drinking, and not with exposing one's skin, eyes, ears, and nasal passages through recreational water contact.[20] Keeping this distinction in mind is useful in understanding what is, and is not, monitored as part of regular water-quality testing.

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19 Here are some examples of news reporting on bacteria:

> "They monitor total coliform — a group of bacteria that come from soil, plants, animals and humans — as well as fecal coliform, most of which is the common gut-dweller *E. coli*, along with the ball-shaped *Enterococci*, another intestinal bug that enters the ocean through storm drains. These three 'indicator' bacteria don't often produce illness, but at sufficient concentrations they can indicate the presence of other microorganisms that can make you sick" (Allen, 1999a).
>
> "Honeybourne agreed: 'We aren't measuring for disease-causing organisms. We are using indicators [such as fecal coliform] as a sentinel or surrogate for those diseases because it's difficult measuring the viruses, bacteria and protozoa'" (Reyes, 1998).
>
> "Contaminated water indicates the possible presence of disease-producing bacteria. An elevated concentration of 'indicator' bacteria may be caused by a wide variety of sources, such as decaying vegetation, urban runoff, storm runoff, animal waste or human waste" (Mabbott, 1999).
>
> "The *Enterococcus* bacteria lives in the stomachs of warm-blooded animals, including dogs and humans. It serves as an indicator that there may be other organisms present that cause illness in humans, [Interim Orange County health officer Dr. Hildy] Myers said" "Beach Closure" (1999).

20 Of course, people get water into their mouths and stomachs from recreational activities such as swimming and surfing, too, but the extent of gastrointestinal exposure is not the same as drinking entire glasses or cups of water daily, using it for food preparation, etc. By way of analogy, consider the chlorine levels in swimming pools — people who swim in chlorinated swimming pools often ingest some water when they swim, but they would not tolerate the levels of chlorine in a drinking-water supply that are used in a swimming pool.

Pathogens[21] that cause people to have gastrointestinal illness symptoms are themselves generally from the gastrointestinal tract. Pathogenic bacteria, viruses, and protozoa that reside in or pass through the human digestive system, known as *enteric* pathogens, are usually the agents that cause people to have symptoms associated with waterborne illness — nausea, stomach pain, vomiting, and diarrhea. Often, these symptoms persist for a day or two and, although very uncomfortable, are not life threatening. But, enteric pathogens can cause waterborne illnesses that are extremely serious or even lethal because of the dehydration that can follow severe vomiting and diarrhea. Illness outbreaks have resulted in deaths, even among otherwise healthy adults, when drinking water has been contaminated by bacteria such as *S. typhosa* or *V. comma*. Children or adults in compromised health face a greater likelihood of contracting severe illness symptoms from exposure to enteric pathogens.

Enteric pathogens can find their way into drinking-water supplies when enteric wastes, such as feces and waters contaminated with fecal matter, are not kept separate from drinking-water sources or distribution systems. This has long been a risk in developing and rural areas where people might use open latrines for sanitation and bathe or wash their household goods in the same streams or ponds from which they draw their drinking water. More recently, during the early waves of urbanization and industrialization in Europe and North America in the nineteenth century, large and concentrated quantities of human sewage were often disposed of in ways that did not keep them separate from drinking-water supplies, and cholera outbreaks were common in nineteenth-century cities.

Thus, water-quality testing started from the effort to guard human health by protecting drinking-water supplies from contamination by enteric pathogens. If one could determine whether a water supply was free of enteric wastes, one could decide whether to advise the public to use or avoid it.

This background allows us to return to the topic of water-quality indicators. Water-quality indicators are used because of four properties of enteric pathogens — number of types, size, infective dose, and isolation methodologies.

- ***Number of Types*** — There are thousands of enteric pathogens with the potential to provoke illness symptoms in human beings, and more are discovered all the time (Bishop, 1983). Just listing the most common ones — *Salmonella, Shigella, Leptospira, Pasteurella, Vibrio, Mycobacterium*, cysts of *Endamoeba hystolytica*, hookworm larvae, human adenovirus — gives some indication of their number and variety. Multiple genera and species of bacteria, viruses, and protozoa inhabit the human gastrointestinal environment, and many more can be found in the intestinal tracts of other mammals (though their likelihood of generating illness symptoms in humans is unknown).[22] It would be extraordinarily expensive and time consuming to regularly test water supplies for each of these potential illness-causing organisms — if it were even possible (O'Shea and Field, 1992). Time is an important adversary in public health protection — the longer it takes to detect the presence of pathogens, the longer the public is exposed before remedial or prophylactic measures are taken. As a 1934 British Ministry of Health report observed, by the time the presence of actual pathogens in water supplies was detected, it would tell us little more than what was already known from the

21 The broad name used as shorthand for illness-causing agents, including bacteria, viruses, and protozoa.

22 The issue of cross-species pathogenesis — whether and to what bacteria, viruses, or protozoa from other species cause illness in human beings — is actively discussed but unresolved. We will revisit the issue in connection with our discussion of pollution sources in Chapter 6, because it relates to the question of whether high coastal-water bacteria counts caused by bird droppings or pet waste represent a human health threat that warrants a particular policy response. See Bartram and Rees (2000).

appearance of illness in the public (Cartwright, 1992). Considerable time and money devoted to the protection of public health are saved if some organisms in drinking-water supplies could be used as “signals” that other pathogenic creatures are likely to be present.

- ***Organism Size*** — Pathogens vary considerably in size and, thus, in ease of detection. Protozoa tend to be smaller than most bacteria, viruses are smaller than protozoa, and even within each group there is considerable variation; therefore, in addition to the challenge of detecting multiple types of enteric pathogens in any given water sample, there is the further challenge that some types are easier to detect than others. This variation in the size of organisms further contributes to the desirability of having a few, relatively easier to detect, organisms that can represent the presence (or, at least, possible presence) of others that are more difficult to find (Cartwright, 1992).
- ***Infective Dose*** — Even if it were possible to peer into a water sample and enumerate every type of pathogenic organism within it, there would remain the question of how large a population of an organism represents a health threat. This is the question of infective dose — since pathogenic organisms may be present in the air we breathe, the water we drink, the food we consume, and the surfaces we touch, how much of any type is enough to make us sick? Is one rotavirus, intact and alive in a cup of water, enough to infect an individual? What about two or 20? And, is that the same as the number of *Giardia* cysts or *E. coli* bacteria in a cup of water that would make a person sick? These questions may even be unanswerable because the infective dose could vary not only from species to species of pathogen, but also from one exposed person to the next. The relationship between the presence of pathogens and the likelihood of illness will, therefore, almost certainly have to be addressed in the aggregate — in terms of associations or correlations between pathogen densities in water and illness rates in exposed populations. And, if that is the case, it arguably makes more sense to use some organisms in the water as surrogates for all pathogens rather than to try to set infective dose targets for each type of potential waterborne pathogen.
- ***Detection Methodologies*** — Several of the above statements have employed expressions such as, “even if it were possible,” as a way of capturing the limitations of our abilities to identify and enumerate organisms in water samples. For each species, methods must be developed that allow researchers and public health officials to identify and enumerate its presence in a sample of water (or, at least, estimate it within an acceptable range of expected error). Despite the remarkable progress in water science and technology over the past century, there remain many pathogenic and potentially pathogenic organisms for which no detection methodology has yet been developed (Bartram and Rees, 2000); therefore, the kind of information that we would need to protect the public from exposure to infective doses of pathogens of all types and sizes simply does not exist. Thus, in the last instance, it is out of sheer necessity that we draw inferences about the presence of some organisms from the detection of others.

Combined, these characteristics of enteric pathogen populations in the aquatic environment have driven the search for water-quality indicators — a manageable number of easily detectable organisms whose presence in a water sample can inform researchers and public health officials that other potential illness-causing agents are probably present, too. The search dates back at least 100 years to the work of Escherich and his fellow biologists at the turn of the twentieth century, who identified a family of coliform bacteria that were relatively harmless and easy to detect, and were always found in feces (Bartram and Rees, 2000), which made them potentially useful markers for the possible presence of enteric pathogens. Since then, coliform bacteria and *Enterococci* (often referred to as fecal streptococci) have become the most commonly used indicators of fecal contamination in surface waters.

Compared with the potential time, expense, and complexity of testing water samples for all waterborne pathogens, the indicator approach has obvious and considerable practical benefits. It is also inherently limited. The very properties that make indicators useful also make them imperfect. The use of indicators is a pragmatic choice — a tradeoff of cost and feasibility versus precision.

Indicators are “circumstantial evidence” of the presence of actual pathogens and such evidence is, therefore, “often open to doubt in its interpretation” (Cartwright, 1992). Microbial indicators of water quality serve only as guides in determining potential exposure to pathogens (Davis et al., 1977) and “must always be regarded as an estimate of the water quality at the time and site of sampling, rather than as an absolute determination” (Bartram and Rees, 2000).

In summary, microbial water-quality indicators are used to simplify the water-quality monitoring process by substituting more easily detected organisms for the ones we are really interested in but which are harder or impossible to detect. Critics might be reminded of the old joke about the inebriated gentleman who was found on the sidewalk on his hands and knees, looking for his keys. A passerby who stopped to help the man asked, “Where were you standing when you dropped them?” The besotted fellow replied, “Over there, in my yard.” So the passerby asks, “Then why are you looking over here on the sidewalk?” “Because,” the man answers, “the light’s better over here!” When we count indicator organisms in water samples rather than the actual pathogens we are concerned about, in a sense we are doing so because “the light’s better over there.”

## 2. Properties of a Good Indicator

Although “there is no ideal indicator” (Cabelli, 1979), there are properties that make some better and others worse. Previous researchers have described characteristics that are desirable in a water-quality indicator. These desirable properties reflect both the purposes for which indicators are used and the cautions about their nature as approximations for, rather than actual measures of, pathogens. Here is a brief summary of these properties:

***Applicability to the Type of Water Environment in Question***

Because microbial indicators are themselves living organisms, they will survive better in some environments than others. An obvious distinction is that between salt water and fresh water environments, which has been a critical consideration in the selection of indicators for monitoring coastal water quality. Other such differences among water environments include warm tropical waters versus temperate or arctic waters.

***Hardiness and Survival Time***

A useful water-quality indicator should be present and detectable in waters for as long or longer as the longest-lived pathogens of concern (Bishop, 1983). It should also display the same or similar resistance to disinfectants, toxins, and environmental stress as the most resistant pathogens of concern (Cabelli, 1979). If an indicator dies off sooner than the illness-causing agents of concern, indicator concentrations will diminish or disappear while the water still poses some hazard to people.

***Adequate Abundance***

When present in water samples, the indicator organism should exhibit large enough concentrations (i.e., the number of organisms per given volume of water) to make estimations of its concentration reasonably accurate within expected error ranges (Cabelli, 1979). All other things being equal, the smaller the concentration of organisms, the greater the variance (and uncertainty about the true variance) from sample to sample and, thus, the greater the difficulty in drawing inferences about water quality.

***Correlation with Pathogen Presence***

There are two aspects of this property. First, as a baseline condition, a desirable indicator should be present in water whenever pathogens of concern are present. Second, to enhance the indicator's usefulness, there should be some positive and reasonably predictable correlation between the concentration of the indicator organism and the concentration of the pathogen or pathogens of concern (Bishop, 1983).

***Identification with a Source***

There are two aspects to this property, also. First, the indicator organism should not reproduce in the contaminated water environment. The indicator's presence in a water environment, or an increase in its concentration, should reflect contamination of the water environment and not the natural reproduction of the indicator organism itself. Second, a useful indicator should have a known (and limited) origin. This aids public health officials in determining the health threat posed by the water. Enteric pathogens of human origin, for instance, are more likely to cause illness in humans than enteric pathogens of non-human origin. Close identification of an indicator with its source(s) also aids efforts to improve water quality, if needed. The fewer possible sources of the indicator organism, the more useful it can be in identifying the water quality culprit(s) affecting a particular location. For these reasons, an indicator organism that comes only from human sources would be more useful than one associated with several warm-blooded mammal species, while the latter would be more useful than an indicator that could come from animals or plants, and so on.[23]

***Ease of Detection Methodology***

The indicator organism should be detectable by reasonably simple and inexpensive, yet accurate and reliable, methods (Cabelli, 1979; Bishop, 1983). As noted in the previous section of this chapter, the justification for using water-quality indicators in the first place (instead of trying to directly isolate and quantify the presence of the actual pathogens) rests largely upon cost and feasibility considerations. The more expensive and difficult the methods for detecting and quantifying an indicator organism, the weaker the justification for employing it at all.

***Harmlessness to Humans***

Although laboratory researchers and public health officials can take reasonable precautions to reduce their own illness risk resulting from the water sampling process, it is nevertheless desirable that the water-quality indicator itself poses little or no risk to human health (Bishop, 1983). In light of all foregoing properties concerning the abundance, accuracy, ease of detection, etc. of an indicator, it would be unfortunate indeed if the water-quality indicator were itself pathogenic. If it were so, we might wish to search for an indicator for the indicator!

23 A useful description of the issues associated with this property appears in Bartram and Rees (2000):

> Rainfall can have a significant effect on indicator densities in recreational waters increasing the densities to high levels because animal wastes are washed from forest land, pasture land and urban settings, or because treatment plants are overwhelmed causing sewage to by-pass the treatment process. In either case, the effect of rainfall on beach water quality can be quite dramatic. The effect . . . on a beach surrounded by forests, was very rapid and usually persisted for 1 to 2 days. The highly variable effect of rainfall on water quality can result in the frequent closing of beaches. The important question is whether high indicator levels that result from animal wastes carried to surface waters by rain water run-off, indicate the same level of risk to swimmers as would exist if the source of the indicators was a sewage treatment plant. There are conflicting reports in the literature with regard to risk associated with exposure to recreational water contaminated by animals (Bartram and Rees, 2000).

### 3. Indicators Currently Used for Coastal Water-Quality Monitoring in California

As discussed in Chapters 2 and 3, the current state law governing coastal water-quality monitoring — AB 411 — identifies microbial water-quality indicators that county public and environmental health officials are to use. Those indicators are TC, FC, and *Enterococci* bacteria. Each of these indicator bacteria is measured in terms of number of organisms per 100 mL — about half a cup of water.

***Total Coliforms (TC) and Fecal Coliforms (FC)***

TC and FC have been used as water-quality indicators for a long time in California and elsewhere. The U.S. Public Health Service (a forerunner of the U.S. Environmental Protection Agency with regard to federal water-quality regulation) recommended in 1968 that states use TC and/or FC for recreational water-quality monitoring. From that time until AB 411 passed in 1997, several coastal counties in California measured the concentrations of TC, FC, or both when determining the appropriateness of recreational water contact at their beaches. AB 411 and the regulations promulgated under it by the California Department of Health Services require the continued use of TC and FC counts, along with an FC-to-TC ratio and *Enterococci* counts.

The coliform group of bacteria are rod-shaped bacilli that appear in large numbers in sewage-contaminated waters and are easy to detect and enumerate by relatively simple laboratory methods (Bishop, 1983). These characteristics, combined with the original concerns of drinking-water supplies being contaminated by sewage, made TC counts the earliest and most widely used microbial water-quality indicators.

The coliform group, however, is large and diverse and includes nonenteric bacteria — that is, types of bacteria that do not come from the human or animal gastrointestinal tract. *Aerobacter, Citrobacter*, and *Klebsiella*, for example, are genera that would be included in a TC count, but may have come from soil or plants and would not necessarily reflect a threat of illness if humans consumed that water.

Researchers, therefore, modified their tests (using different media and higher temperatures) to try to narrow the TC group down to a smaller group of coliform bacteria more likely to have come from enteric wastes. These methods produce counts of the subset of TC known as FC. The most common bacteria within the FC group is *E. coli*, which is strongly associated with enteric wastes. Even FC counts may, however, include *Klebsiella* and other bacteria with nonenteric origins (O'Shea and Field, 1992).

The strength of correlations between known actual pathogens and TC or FC concentrations in water samples has been tested and debated extensively. Geldreich (1970), for example, reported that pathogenic *Salmonella* bacteria could be isolated in 50 percent of water samples with FC concentrations of 200 organisms per 100 mL or more. Vaughn and Metcalf (1975) studied the correlation between FC and *Salmonella* as well as viral concentrations in shellfish, and also judged FC to be a useful indicator (Bishop, 1983).

Other researchers have disagreed. Sayler et al. (1975) questioned whether the correlations between TC and actual pathogens were strong enough to justify the use of TC for public health regulation, and Araujo et al. (1990) and Grabow et al. (1989) also found weak correlations between pathogens and the traditional coliform indicators (Ferguson et al., 1996). Examining the source and presence of pathogens in stormwater runoff, Davis et al. (1977) concluded that TC was not a reliable indicator of the quality of receiving waters.

Reviewing these and other studies in the literature, O'Shea and Field (1992) acknowledged that TC or FC concentrations may be satisfactory to indicate sewage-related contamination of water supplies, but questioned their use outside the sewage-contamination context. On the other hand, they concluded that the "results of a limited number of epidemiological studies strongly suggest that TC or FC indicators cannot be used to accurately assess the pathogenicity of recreational waters receiving stormwater from uncontaminated separate storm sewers or surface-water runoff."

***The FC-to-TC Ratio***

The AB 411 single-sample standards (which, as discussed in the preceding chapter, are also used in Heal the Bay's beach report cards) include an unusual indicator that finds little support in scientific literature on water-quality monitoring and does not reflect long-standing federal and state practice. This is the ratio of FC-to-TC.

Previous researchers such as Geldreich had explored whether ratios like FC-to-TC, FC-to-*Enterococci*, and such might help to narrow the potential source of fecal pollution (human versus animal wastes, for instance). But these explorations had occurred with respect to untreated fresh water sources that might be used for drinking water, not with respect to marine recreational waters. As noted in Chapter 3, it appears that the notion of employing this ratio for a regulatory standard governing the quality of marine recreational water came largely or entirely from the Santa Monica Bay Epidemiological Study. That study concluded (for reasons that were and remain unclear) that the ratio seemed to matter as the TC count rose. The Department of Health Services' explanation for the use of the ratio refers only to the Santa Monica Bay Epidemiological Study and this unaccounted-for statistical finding: [24]

> The Santa Monica Bay investigators found that the ratio of total to fecal coliforms was related to an increase in illness . . . Additional analyses of the data from the Santa Monica Bay study compared the risk of illness among swimmers in water at different total/fecal ratios and at two levels of total coliform bacteria, 5,000 per 100 mL and 1,000 per mL (Haile and Witte, undated). At a total coliform count greater than 5,000 per 100 mL, a total/fecal ratio of 10 (one-tenth of the total coliforms are fecal) was related to risks of 107 to 657 per 10,000 swimmers for eight different effects (fever, eye discomfort, ear discomfort, skin rash, nausea, diarrhea, stomach pain, runny nose). At a total coliform count greater than 1,000 per 100 mL, a total/fecal ratio of 10 was related to risks of 117 to 281 per 10,000 swimmers for three different effects (chills, nausea, diarrhea). The Department incorporated the ratio of the two coliform indicator organisms into the standards to be used . . . The results of the Santa Monica Bay study showed that the ratio of total to fecal coliforms was more predictive of illness than the *Enterococci* concentration (California Department of Health Services, 1999).

It is unusual for public health officials to embrace a potential health standard generally supported by the results of a single study. It is even more unusual for public health officials to adopt a regulatory standard when the results from that single study were uneven. The results of the Santa Monica Bay Epidemiological Study regarding the FC-to-TC ratio exhibited significant variations among the three outfall locations and over time. Despite these varied findings, and despite the fact that the ratio itself has at best a questionable basis in science as a water-quality indicator, both Heal the Bay (see Chapter 3) and the California Department of Health Services have chosen to embrace the ratio as a measure of health risk.

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24 In the Santa Monica Bay Epidemiological Study, the ratio was reported as TC-to-FC — a number that is 1 (if 100 percent of the coliforms were fecal) or greater. The AB 411 regulations incorporate it as a ratio of FC-to-TC — a number that is always between zero and 1. This inversion does not change the substantive concept of the ratio, just the arithmetic of its calculation, but must be understood to avoid confusion when reading AB 411 water-quality reports in light of the Santa Monica Bay Epidemiological Study.

*Enterococci*

The AB 411 regulations also added *Enterococci* bacteria as another indicator but, unlike the FC-to-TC ratio, *Enterococci* has extensive support in the scientific literature on water-quality indicators. The U.S. Environmental Protection Agency has recommended since 1986 that states and local governments adopt *Enterococci* for monitoring recreational water quality in saltwater environments, either in addition to or even as a replacement for the more familiar TC and FC counts.[25]

The preference for *Enterococci* is based on several of the properties of a good indicator discussed earlier in this chapter. *Enterococci* bacteria — ball-shaped organisms that are somewhat smaller on average than coliform bacteria[26] — share with the coliform group the properties of being relatively easy to isolate and count in water samples using reasonably economical detection methods. But the *Enterococci* group surpasses the coliform group on some of the other properties.

- ***Hardiness in the Marine Environment and Resistance to Sunlight and Chlorine***

  First and, arguably, foremost is the hardiness of *Enterococcus* in salt water. Some enteric viruses, such as Hepatitis A, rotavirus, and Norwalk virus, can survive in the marine environment and remain infective to humans for several days (Cabelli, 1979). Jiang et al. (2001) report that laboratory studies have found enteric viruses surviving between 2 to 130 days in salt water.

  Coliform bacteria, on the other hand, die off rather quickly in salt water, with concentrations dropping sharply after 2 to 3 days in the absence of a new source of contamination. Coliforms may, therefore, be absent or at very low concentrations while pathogens remain present (Bishop, 1983) or, by the same token, pathogens could be present at higher concentrations in a salt water sample than in a fresh water sample that shows the same coliform bacteria count (Bartram and Rees, 2000).

  *Enterococci* bacteria survive longer in salt water — as long as 2 weeks. Researchers have, therefore, concluded that the *Enterococcus* group comes closer to tracking the duration of pathogen presence (Bartram and Rees, 2000, 1980; Borrego et al., 1983; Sinton et al., 1993a,b).

  Coliform bacteria die off at an increasingly rapid rate when exposed to sunlight. *Enterococci* bacteria die off at a rate that appears to be unaffected by sunlight exposure and, therefore, survive longer in sunlight than coliform bacteria. Coliphages — viruses that infect coliform bacteria — also survive longer when exposed to sunlight. If other viruses behave similarly to coliphages, longer survival would also support the superiority of *Enterococci* as a tracer for these pathogens in shallow water environments, such as the near-shore coastal region, where the top several feet of water are affected by sunlight (Bartram and Rees, 2000).

  Furthermore, *Enterococci* bacteria are not damaged as readily as coliform bacteria by chlorine exposure. Wastewater treatment relies heavily on chlorination to kill many bacteria, but other pathogens (again, some viruses and protozoa) survive chlorination and

25 In 1999, for example, Palm Beach County, Florida, received funding from the U.S. Environmental Protection Agency to switch its ocean water-quality testing from TC to *Enterococcus*. And, in 1997, the U.S. Environmental Protection Agency ordered the Orange County Sanitation District to incorporate *Enterococcus* into its water-quality testing as a condition of extending the district's waiver from Clean Water Act requirements of secondary treatment of all wastewater prior to ocean discharge.

26 Outside the United States, *Enterococcus* bacteria are commonly referred to as fecal streptococci. Although researchers have differed on whether every species identified under these two genera are identical, reviews of the literature by Leclerc et al. (1996) and Bartram and Rees (2000) concluded that, as a practical matter, the terms *Enterococcus* and fecal streptococcus can be used interchangeably, and research results on survival rates, correlation with pathogens, etc., may be regarded as equivalent whether reported in terms of *Enterococci* or fecal streptococci.

may, therefore, be discharged into the marine environment (Cabelli, 1979). The comparative resistance of *Enterococcus* to chlorine provides another advantage as a marker for potential pathogen presence in sewage-impacted waters (Bartram and Rees, 2000).

- ***Correlation With Pathogens and Illness Symptoms*** — Examinations of the relationships between *Enterococci* densities in water samples and the presence of actual human pathogens also support the preferability of *Enterococcus* to coliforms as a microbial water-quality indicator (Bartram and Rees, 2000). Partly because of the greater hardiness of *Enterococci*, their concentrations have been found to correlate better with pathogens and with the frequency of gastrointestinal illness symptoms reported by recreational water users.

  Of particular interest is a study conducted by Davis et al. (1977) of indicator and pathogen concentrations in stormwater runoff. They sampled stormwater above and below an urbanized portion of the Houston metropolitan area and compared microbial indicator densities in the runoff before and after storm events. They also compared each of three water-quality indicators — TC, FC, and *Enterococci* — with the presence of the known pathogens *Pseudomonas, Staphylococcus*, and *Salmonella*. They found that *Enterococci* counts correlated better than either TC or FC with the presence of each of the three pathogens.

  Epidemiological studies conducted by researchers for the U.S. Environmental Protection Agency correlated illness symptoms of recreational water users with the densities of three water-quality indicators — FC, *E. coli*, and *Enterococci*. These studies included both fresh water and salt water recreational sites. The studies used regression and correlation analysis to assess the strengths of each type of indicator in signaling the health risks associated with recreational water contact.

  In both kinds of environments, the correlations between FC concentrations and gastrointestinal illness symptoms were so weak as to call the validity of FC as a health-effects indicator into question (O'Shea and Field, 1992). The findings of the U.S. Environmental Protection Agency studies were consistent with other research reported by Dutka (1973) and Fujioka and Shizumura (1985) (O'Shea and Field, 1992).

  By contrast, the correlations between gastrointestinal illness symptoms of swimmers and the mean concentrations of *E. coli* (in fresh water) or *Enterococci* (in salt water) were very strong, r= 0.95 (Cabelli, 1979).[27] And the preferability of *Enterococci* as an indicator in salt water was supported by findings that, for equivalent *Enterococci* densities in salt water and fresh water samples, the rates of gastrointestinal illness symptoms were three times higher at salt water recreational sites than at fresh water sites (O'Shea and Field, 1992). This suggested that *Enterococci* densities in salt water were more likely to track the presence and persistence of pathogens; therefore, health-based standards for salt water and fresh water should probably be based on different indicator organisms.

- ***Source Identification*** — *Enterococci* bacteria may also have advantages over coliforms by virtue of being associated with a smaller set of possible sources. As mentioned earlier in this chapter, coliform bacteria may have non-enteric origins, including soil and plants.

27 *Enterococci* and *E. coli* both correlated well with pathogen presence in fresh water, but *E. coli* has other properties that, in the view of the U.S. Environmental Protection Agency, made it preferable to *Enterococcus* as a fresh-water quality indicator (O'Shea and Field, 1992). Accordingly, the U.S. Environmental Protection Agency's recommendations to the states since 1986 have included the use of *Enterococcus* for marine water environments and *E. coli* for fresh water settings.

Although there have been reports that some biotypes of *Enterococcus* have been found in plants and insects (Geldreich, 1967), the *Enterococcus* genus of bacteria generally has a more limited set of sources than coliforms and are always present in the feces of warm-blooded animals (Bartram and Rees, 2000). *Enterococci* may grow in fresh urine, but do not appear to multiply in sewage-contaminated waters so their concentrations are likely to reflect source contamination rather than their own reproduction (Bartram and Rees, 2000).

In summary, then, the body of scientific research on water-quality indicators[28] supports the use of *Enterococci* as at least as good as (and, in marine environments, probably preferable to) the more commonly used coliform bacteria indicators. The addition of *Enterococci* to AB 411, unlike the addition of the FC/TC ratio, can be said to represent an improvement in the scientific foundation underlying California's coastal water-quality monitoring regime. This does not mean that the set of indicators employed under the AB 411 regulations is without problems, however.

## 4. Problems with the Current Indicators and Their Use — False Positives and False Negatives

By nature, water-quality indicators are imperfect and imprecise. This section discusses the problems that are created by relying on these indicators. The microbial indicators used for coastal water-quality monitoring in California have some notable shortcomings. Water testing that relies on those indicators can yield both false positives and false negatives.

False positives occur when indicator readings exceed regulatory standards, resulting in beach warnings or closures, even though the actual water quality may pose acceptable risks to recreational water users. False positives have consequences — lost recreational opportunities for residents and visitors, financial losses for beach-related businesses, and perhaps unnecessary effort and expenditures for remedial measures to improve coastal water quality.

False negatives mean that the water-quality indicators fail to detect substantial risks to recreational water users. False negatives have consequences, too — avoidable illnesses experienced by beachgoers and, possibly, inadequate measures taken to improve coastal water quality.

### *Causes of Both False Positives and False Negatives*

Three characteristics of these indicators and their use can contribute to either false positives or false negatives. In other words, because of these problems, indicator readings (and the beach warnings or closures based on them) can create the appearance that coastal water quality at a particular location violates health standards when it does not or, conversely, is in compliance with health standards when it is not.

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28 Researchers have certainly not stopped with the coliform group and *Enterococcus*. Other water-quality indicators that have been investigated include:

*Coliphages:* These have been recommended because they are abundantly available in sewage, correlate well with the presence of enteric pathogens (Bishop, 1983), and survive chlorination and salt water well. But attempts to isolate coliphages in significant numbers from human feces have been unsuccessful, so their presence in sewage-contaminated waters may not indicate fecal contamination per se (Cabelli, 1979).

*Candida albicans:* These also survive chlorine and salt water, but are not consistently present in feces in adequate numbers to serve as an indicator (Cabelli, 1979).

*Clostridium perfringens:* These spores are found in prolific numbers in sewage and also survive chlorination and salt water well. But they are also found in soils and bottom sediments, which complicates their use as water-quality indicators if bottom sediments are occasionally disturbed and get into the water column (Cabelli, 1979).

*Bifidobacteria:* These are excellent for source identification, as they are almost exclusively associated with human rather than animal feces, but they do not survive chlorination or salt water well (Cabelli, 1979).

*Coprostanol:* This nonbiological indicator is a steroid produced when enteric bacteria mix with cholesterol in the gastrointestinal systems of higher animals. It may also be present in large enough quantities to be detected easily (Bishop, 1983). It is not clear what the drawbacks are.

*Salmonella:* Although a good indicator that other pathogens are present, *Salmonella* is more difficult to enumerate precisely than other indicators and is certainly not harmless to humans.

- ***Sampling and Measurement Error*** — The degree of precision with which water-quality indicators reflect the actual quality of the water at a particular location is subject to two sources of error. One is sampling error, which has to do with the relationship between samples and the water from which they are taken. Indicator densities for a particular beach site are calculated from a water sample collected from that site. Any time a sample is used to draw inferences about the larger population from which it was taken, there is the prospect that the sample differs to some degree from the population that it is supposed to represent. These errors can be estimated using the mathematics of probability, provided certain assumptions are made about the randomness of the sampling process (in other words, assuming that water samples are not collected in a manner that deliberately or systematically biases the sample characteristics in a particular direction). The existence of sampling error creates the possibility that indicator densities calculated from a sample will be higher than the indicator densities in the larger body of water from which the sample was collected (possibly yielding a false positive result), and also the possibility that the indicator densities calculated from the sample will be lower than those in the body of water from which the sample was taken (possibly yielding a false negative result).

  Another source of error may be called measurement error. Indicator densities are calculated from water samples using detection methods that isolate indicator bacteria through a culturing or fermentation process, and then enumerate the number of organisms from observation of the surface media on which the bacteria were isolated. These detection methods are well developed and widely used[29] but, of course, the isolation and enumeration processes can yield density counts that differ to some degree from the "true" (albeit unknown) indicator density that existed in that water sample before the detection process began. As with sampling error, measurement error can produce inaccuracies in either direction, producing false positives (density calculations higher than the actual density) or false negatives (density calculations lower than the actual density).
- ***Correlation Error*** — Another source of error has nothing to do per se with how water-quality indicators are collected and calculated, but with their very nature as indicators. As noted throughout this chapter, microbial water-quality indicators are not themselves the illness-causing (pathogenic) organisms that we are concerned with in monitoring water quality to protect public health. The indicators are organisms that we use because their presence signals the possible presence of the pathogenic organisms with which we are concerned.

  The indicators are correlated with, not identical to, those pathogens. And correlations are sometimes less than 100 percent. Indicator densities in a water sample may be high when actual pathogens are low or even absent — a false positive. One might detect numerous coliform bacteria, for example, in a water sample where actual enteric pathogens such as *Salmonella* or rotavirus are completely undetected or are present in concentrations low enough to pose little or no risk of infection for humans swimming or surfing in the water.

  But correlation errors, like sampling and measurement errors, work in both directions. Indicator densities may be low when actual pathogens are present — a

29 Even among widely used methods, there may be differences of precision. Some detection methods may be preferable to others if their error margins are narrower.

false negative. It is possible, for example, to isolate little or no *Enterococci* in a water sample where actual enteric pathogens appear in concentrations that pose infection risks to recreational water users. Jiang et al. (2001), for example, report finding human adenovirus in water samples taken from several stream mouths along the Southern California coast, including some sites where the AB 411 set of water-quality indicators (TC, FC, and *Enterococci*) measured safely inside the standards for recreational water use.

For as long as water-quality indicators have been used, researchers have tried to ascertain how well each indicator correlates with actual pathogens. We have already mentioned Geldreich's finding concerning *Salmonella* and FC, and Cabelli's correlation of *Enterococci* readings with gastrointestinal illness symptoms. An overall view of the literature presents mixed findings: some studies have found strong correlations between indicator densities and pathogen presence, and other studies have found weak or little correlation between indicator densities and pathogen presence (for other reviews of the literature, see O'Shea and Field [1992] and Bartram and Rees [2000]). Some of the differences among the reports may be attributed to which indicators were being tested against which pathogens. Other differences undoubtedly had to do with the water that was sampled and the contaminant sources to which it was exposed. The composite result may be characterized as follows: if you are trying to form a judgment about the risks associated with water recreation at a particular beach, having information about the indicator densities in a water sample from that beach is better than having no information at all, but it still leaves you substantially open to judging the risks erroneously.

- ***Measurement and Reporting Delay*** — A third contributor to false positives and false negatives in the use of the AB 411 indicators (or any other bacteriological water-quality indicators currently in use) is the time lag between the collection of a water sample and the posting of a beach warning or closure. Once a water sample is collected, it must be transported to a laboratory where the detection methods are applied to generate the indicator density calculations. The culturing processes at the heart of those detection methods take several hours. At the end of those processes, the enumeration of organisms from each sample takes place. Those organism counts for each beach site are communicated to the county environmental health officials, who then apply the AB 411 standards and determine whether and where to post health warnings about recreational water use.

  At present, water samples are taken early in the morning, and the lab work of identifying and enumerating indicators consumes 24 to 48 hours, so the earliest the results might be available to make determinations about beach warnings and closures is the following morning. The warnings and closures that occur along California's coast are typically based on indicator densities calculated from the previous day's samples.

  Does this delay matter? It certainly can. Consider the following three consecutive days at the Magnolia Street sampling station at Huntington State Beach in Orange County, California. The AB 411 single-sample standard for *Enterococcus* concentrations is 104 organisms per 100 mL. On Friday, August 28, 1999, the *Enterococci* reading from the Magnolia Street site was 110. On Saturday, August 29, it shot up to more than 400. On Sunday, August 30, it plummeted to 16 (Robbins, 1999j).

  If Sunday's beach warning were based on Saturday's water sample, people would have been warned not to swim or surf at that portion of Huntington Beach even though Sunday's *Enterococci* reading at that site suggests that the water would have been perfectly acceptable under AB 411 standards — a classic example of a false positive and its negative consequences for beachgoers and beach businesses.

On the other hand, the same variability in indicators can produce the opposite result. Simply imagine the days reversed, so that one-day's *Enterococci* reading is 16 and the next day's is 400. On the latter day, the beach would be open and no health warnings would be posted because the previous day's reading indicated all was well, but swimmers and surfers would actually be in contact with water that had *Enterococci* readings far in excess of the AB 411 standards.

The delays that currently occur between sampling of water and posting of beaches can, therefore, contribute to either false positives or false negatives. In effect, beachgoers are in the position of deciding whether to swim or surf today based on yesterday's water-quality readings.[30] Researcher Dr. Stanley Grant of the University of California, Irvine, has colorfully compared this to driving the Southern California freeways using yesterday's SigAlert information.[31]

***Another Cause of False Positives: Multiple Sources of Indicator Bacteria***

Earlier, it was stated that coliform bacteria found in water samples may originate in numerous sources besides the human gastrointestinal tract, including animal wastes, soil, and plants. There are also many non-human sources of *Enterococci*, including the wastes of other mammals and of birds (Bartram and Rees, 2000). *Enterococci* species have also reportedly been isolated from plants and insects, although these insects and plants may have simply been carrying the bacteria externally and not have been its source (Leclerc et al., 1996). A few strains of *Enterococci* were even isolated in relatively pristine waters in Finland, leaving open the possibility that some species of *Enterococcus* may occur in the environment apart from fecal pollution (Leclerc et al., 1996).

The existence of multiple sources of coliform and *Enterococci* bacteria contributes to the prospect of false positives resulting from their use as water-quality indicators for human recreational water contact. It is highly unlikely that coliform bacteria contributed to waters by soil and plants would be indicative of pathogens that would present a substantial risk of human illness. Furthermore, the presence of plant and soil coliforms in water probably bears no relationship to the presence of pathogens contributed by human or animal fecal wastes. Nevertheless, these bacteria may be washed into coastal waters by rainfall or stream flow, and the resulting coliform readings trigger beach postings.

Indicator bacteria that are of enteric origin, but not human enteric origin, may not signal a health risk to human beings from recreational contact. As noted earlier in this chapter, the extent to which cross-species pathogenicity exists (e.g., human illness resulting from exposure to bird or dog enteric bacteria) remains uncertain. Yet, bird droppings on or adjacent to a beach have been associated with high *Enterococci* readings that spark beach warnings or even closures under AB 411 regulations. While there are undoubtedly aesthetic considerations that may reasonably discourage people from wanting to swim in water that is infused with bird droppings, the health risks of such contact are far from clear.

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30 Because of this day-to-day variability in bacteriological water-quality indicator concentrations, it is arguably preferable to assess water quality over a certain period using log-mean values. This might give a more reliable picture of the water-quality conditions at one beach compared with another. It is not as clear how the mean values over a period of time would aid recreational water users in deciding whether to swim or surf at a particular location on one day compared with another.

31 In Southern California, a SigAlert is a radio announcement sent out by the California Highway Patrol to make the community aware of an incident on the freeway that will block one or more lanes for at least 30 minutes. It was named for Loyd Sigmon, its inventor, who was co-owner of radio station KMPC in the 1950's. Mr. Sigmon's original idea was to give the Los Angeles Police Department direct access to Los Angeles radio stations to broadcast emergency public safety information. Each radio station was given a receiver that had "SigAlert" stamped on its side. Source: http://kfwb.com/trafques.html

O'Shea and Field (1992) place particular emphasis on this issue of multiple sources in their assessment of the suitability of using traditional coliform indicators outside the context of sewage-related water contamination. Taking up the point made earlier in this chapter — namely, that the use of these indicators originated with the goal of protecting drinking-water supplies from contamination caused by sewage — O'Shea and Field raise doubts about their applicability to recreational waters impacted by storm-water runoff. Coliform readings in water not receiving sewage are likely to reflect other sources besides human enteric wastes and, thus, may not signal the threat of gastrointestinal illness from recreational exposure. They write, "For stormwater uncontaminated by sanitary wastewater, traditional fecal indicator levels may misrepresent the disease-causing potential of the stormwater, resulting in the premature closing of beaches and the unwarranted adoption of costly disinfection and control measures."

This is a direct statement of the problem of false positives, or positive values derived from inadequate characterization of water quality. The indicator bacteria used for AB 411 water-quality monitoring can produce readings that exceed the health standards for recreational water contact, even when there may be little or no illness risk for humans because the bacteria readings reflect contributions from non-fecal sources.

***Additional Causes of False Negatives***

O'Shea and Field (1992) also stated: "In general, criteria based solely on TC or FC densities inadequately represent the actual human-disease contraction potential, i.e., pathogenicity of a storm flow and its receiving water, causing a misguided concern over some disease hazards and the neglect of others" (O'Shea and Field, 1992). In this section, we elaborate on their last point about the inadequacies of the indicators contributing to a neglect of other health hazards. If the testing currently performed in California with bacterial indicators overlooks other potential waterborne health risks, then low microbial indicator readings may be false negatives. This may occur for any of the following three reasons, all of which reflect criticisms from the published scientific literature that have been directed toward bacterial indicators.

- ***Failure to Test for Non-Gastrointestinal Pathogens.*** As noted earlier, the current microbial indicators used in coastal water-quality testing were borrowed from the regulatory regime for controlling wastewater pollution and protecting the water that people consume. Thus, the presence of most commonly used indicators is intended to signal the possible presence of pathogens originating from the gastrointestinal tract and likely to produce gastrointestinal illness, if ingested. This exclusive focus on enteric bacteria leaves us without direct markers of the presence of non-enteric pathogens (e.g., staphylococci, *Klebsiella, Pseudomonas aeruginosa*, and adenoviruses) (O'Shea and Field, 1992).

  This is an especially telling weakness. A half-century's accumulation of studies of swimming-associated illness[32] show that non-enteric illnesses — disorders of the skin, eyes, ears, or respiratory system — account for half or more of the symptoms experienced or reported by recreational water users (Stevenson, 1953; Seyfried, 1985a,b; Favero, 1985).

  The question then becomes how well the bacteria used as indicators of water quality correlate with the non-enteric pathogens that may be producing the majority of swimming-associated illness symptoms. Unfortunately, the answer appears to be not very well.

  Even Victor Cabelli, researcher for the U.S. Environmental Protection Agency

32 Chapter 5 discusses these studies and the information they provide about the health risks associated with recreational water exposure.

and one of the most persistent advocates of the use of FC as a water-quality indicator, acknowledged: “Most of the case and outbreak reports of swimming-associated illnesses were non-enteric in nature and included diseases such as otitis externa, leptospirosis, swimmer’s itch, and skin and upper respiratory complaints. Since the aetiologic agents of these diseases do not have their source in the faecal wastes of infected individuals, they could not be expected to be indexed by the classical faecal indicators” (Cabelli, 1979). Reviewing the epidemiological literature on swimming associated illnesses, Cartwright concluded that commonly used bacterial indicators may be associated with gastrointestinal illness risks, but “such an association is not necessarily true for ear, eye, and upper respiratory tract symptoms” (1992). O’Shea and Field’s (1992) literature review echoed that recreational water users’ risks of exposure to nonenteric pathogens “cannot be estimated using FC densities alone.”

*Enterococci* may perform better. Davis et al. (1977) reported a fairly strong correlation (r= 0.76) between *Enterococci* and staphylococcus densities in their stormwater runoff samples. Their study, however, is the only one to report correlations between commonly used indicators and non-enteric pathogens in runoff samples, so conclusions cannot yet be drawn about how reliable the association would prove to be across multiple sites.

The weakness of the bacterial indicators in detecting non-enteric pathogens is a “false negative” problem of substantial concern. Staphylococci, for example, have been found in recreational waters even when coliform bacteria were absent (Dutka, 1979). Recreational water users, therefore, may be exposed to illness-causing pathogens that a more effective monitoring regime would have warned them about or kept them away from. There are risks and economic losses associated with the avoidable illnesses that result.

Some researchers have suggested the adoption or addition of non-enteric water-quality indicators for recreational waters, especially to identify health risks due to contaminants other than those borne by sewage. O’Shea and Field (1992) recommended that the “adoption of multiple indicators (e.g., enteric and nonenteric bacteria) or alternative fecal indicators whose densities can be better correlated with nonenteric infections may be necessary to provide a more accurate estimate of the total health risk associated with stormwater contact.”

Staphylococci densities, for example, were found to correlate well in a dose-response relationship to non-enteric illness symptoms experienced by swimmers in fresh water studies (Seyfried et al., 1985). Staph bacteria are believed to be shed in recreational waters from the skin and respiratory tracts of swimmers themselves. A particular infective species, *Staphylococcus aureus*, correlates especially well with the number of swimmers in the water (Dutka, 1979).

*Pseudomonas aeruginosa* is another prospective non-enteric indicator that correlates poorly with gastrointestinal illness symptoms (Cabelli, 1983), but shows a strong association with skin and ear infections. That combination “signifies its potential importance in evaluating the health hazard of waters receiving storm runoff” (O’Shea and Field, 1992). Staphylococci or *P. aeruginosa* may have promise in this regard, but further work specifying either indicator’s minimum infective does and correlation with disease incidence would be needed prior to the adoption of numerical standards (Evison, 1979).

- ***No Direct Testing for Viruses.*** Beaches can test clean for indicator bacteria while human viruses persist in the water. This has been known since 1979, when testing at Galveston Bay, Texas, contained up to 245 plaque forming units (pfu)[33] per 400 liters, even though the same water samples showed no detectable FC and the beaches were open for recreational activity (Bishop, 1983). Human viruses are of particular concern, even for recreational water contact because, compared with indicator bacteria, they have a specific human source and can be infective in smaller concentrations with less ingestion of water than bacterial pathogens (Cone, 1999b).

  Recently, Jiang et al. (2001) tested for the presence of traditional bacterial indicators and for human adenovirus at several locations along the Southern California coast. They found viruses present at the mouths of the San Gabriel and Santa Ana rivers despite the fact that indicator bacteria concentrations at those sites were below the AB 411 regulatory standards.[34] On the other hand, water at the mouths of Malibu Lagoon, Moonlight Creek, and the Los Angeles River had bacterial indicator concentrations that exceeded standards, but adenovirus was found only at the Los Angeles River site.

  The poor association between bacterial indicators and viral presence is consistent with prior work performed by Rachel Noble of the Southern California Coastal Water Research Project, who has conducted approximately 100 tests for viruses at Southern California beaches since the mid-1990s. Noble has detected viruses in about half of her samples, often at locations where the water met bacterial standards (Cone, 1999b). It is not surprising, then, that researchers have concluded "that conventional bacteriological indicators may not be suitable indicators of viral disease hazards in marine waters," (Bishop, 1983) or that "the use of bacteriological indicators to predict the virological quality of water is questionable" (Jiang et al., 2001). Yet, the quest for other better indicators remains to be completed.

  Jiang et al. (2001) pursued adenovirus for several reasons. It is the only human enteric virus that contains DNA rather than RNA, making it amenable to DNA testing methods that are fairly well-established, even if expensive and time-consuming. Adenoviruses are often found in large quantities in sewage and could, therefore, double as an indicator of fecal contamination in water. And they are extremely long-lived, even in sea water — three times as long as Poliovirus, for example, and nearly as long as the hardiest viruses detected to date (Jiang et al., 2001).

  Other researchers have promoted the use of F-specific coliphage as an indicator of fecal contamination, viral presence, or both (Bartram and Rees, 2000). Jiang et al. (2001) found an extremely strong 0.99 correlation between F-specific coliphage and adenovirus concentrations in their samples. Other studies, however, have produced mixed results.

  Of course, as was mentioned earlier in connection with nonenteric pathogens, the incorporation of any viral indicator into a coastal water-quality monitoring regime would depend upon the achievement of some scientific consensus of minimal infective dose and the correlation between viral concentrations and illness incidence.

33 Virus concentrations are reported in terms of plaque forming units (pfu) per stated volume of water.

34 This should not be misread as indicating a specific extent of health risk at those locations. The polymerase chain reaction testing method used to enumerate viruses can count virus fragments as well as intact viruses, and does not indicate whether a particular virus is infective (Jiang et al., 2001). Those determinations would require further work. The Jiang et al. study simply underscores the weakness of the relationship between bacterial indicators and viral presence.

These have not yet been achieved and will depend upon the completion of further research.

- ***No Testing for Toxics.*** Coastal waters that are affected by urban and stormwater runoff are especially likely to receive toxic — in addition to microbiological — contaminants. These toxics pose health hazards to humans from internal exposure (consumption) or external exposure (contact with skin, eyes, respiratory tissues). They include metals such as lead and copper, solvents and other chemicals, and gasoline and other petroleum products.

  The beach monitoring program governed by AB 411 does not test for toxics. Apart from logic or intuition suggesting that if bacterial pollution reaches the ocean from land sources, toxics would be carried along by the same or similar pathways, there is no relationship between the indicator bacteria currently used for coastal water-quality monitoring and the presence and levels of toxics.

  The beach monitoring program's omission of toxicity evaluation reflects the program's focus. The beach monitoring program is directed primarily toward protecting public health by preventing acute illnesses that may be caused by a single exposure, such as the gastrointestinal symptoms that can result from infection by *Salmonella* or rotavirus, or the skin or respiratory symptoms created by a staph infection. While it is certainly possible for acute illness symptoms to result from a single exposure to a toxic substance (mercury poisoning, for example), toxics more commonly impair human health through repeated and/or prolonged exposure — through the buildup of contaminant levels in the blood or tissues, manifested later in organ failure, cancer, or other illness.

  Toxics also differ from biological contaminants such as enteric pathogens in that toxics pose health risks to marine animals as well as people. When researchers perform toxicity evaluations of coastal waters, they often do so by observing and recording the effects on plants such as kelp and animals such as abalone and sea urchins.

  Although the processes of exposure and illness may be quite different for toxics than for biological contaminants, toxics have been found in runoff-impacted coastal waters. Researchers with the Southern California Coastal Water Research Project (Southern California Coastal Water Research Project, 1993; Bay et al., 1996) have measured toxicity levels in dry-weather storm-drain runoff reaching the coast and found it to be in excess of the "no observable effects" concentrations that leave marine life unaffected.

  The absence of measures for toxics in routine water-quality testing performed under the requirements of AB 411 is in itself, therefore, a sort of false negative. Just because we do not test for toxics does not mean that they are not there.

### 5. The Current Coastal Water-Quality Testing Program in California

If our coastal water-quality indicators are so flawed, if they present so many possibilities for false positives that unnecessarily close beaches or for false negatives that might expose beachgoers to avoidable illnesses, then why do we persist in using them? Why rely on bacterial indicators that may not correlate well with the presence of illness-causing agents in the water? More specifically, why not perform direct testing for pathogens such as *Salmonella*, pseudomonas, adenovirus, and such? And why not reduce the delay between sampling and action to make today's beach warnings and closure reflect today's water-quality measures?

The questions nearly suggest their own answers. The traditional bacterial indicators are familiar and well-known, with sampling and detection methods that (by the standards of contemporary laboratory research) are relatively quick and inexpensive. Testing more precisely for a broader array of health threats may be technically feasible, but would increase the costs of water-quality monitoring programs to the public several fold. Virus testing, for example, could cost $700 to $1,000 per sample compared with $20 for current coliform culture tests. Results also take longer than the 24 hours currently required for bacterial indicator testing (Cone, 1999b).

California's current practice under the AB 411 system is a compromise. It incorporates some elements backed by science, such as more frequent testing and the addition of *Enterococci* as an indicator. But the choice of indicators that are used and the testing that is done also reflect limitations of funding and staffing.

Could we do better? Certainly, but not without significantly more money and personnel devoted to the task. And that begs not only a financial question, but a political one as well. Would individuals and organizations who fault the current testing program as "inadequately precise" be willing to support a better one — one that enumerates viral as well as bacterial pathogens, and non-biological as well as biological contaminants, and does so with greater precision and speed? Will local and state officials — and their constituents, with some of the highest stakes in the outcome — be willing to spend more money for more accurate results if that could mean more bad news?

# CHAPTER FIVE
# RECREATIONAL WATER QUALITY AND HEALTH RISKS

*"Swimming in polluted water causes every manner of unpleasantness from earaches to diarrhea, or so goes the conventional surfer wisdom.*

*"The link between polluted ocean water and illness is so ingrained in California beach culture as to seem irrefutable.*

*"But before epidemiologists can definitively link the gunk in the water to the gunk in surfers' chests and noses, researchers will have to figure out how to separate water exposure from all the other factors that could get a person sick.*

*"'Maybe they went surfing, but they also ate out and were around other people,' said county epidemiologist Dr. Hildy Meyers."*

*~ Mayrav Saar,*
THE ORANGE COUNTY REGISTER,
*February 6, 2001*

The usefulness of microbial indicators of recreational water quality depends upon how effectively they signal the health risks people face as a result of water contact. If the concentrations of an indicator correlate well with the frequency of illness symptoms among swimmers and surfers, that indicator provides useful data to public health officials who are responsible for informing the public about the advisability of recreational water contact.

Correlations between illness symptoms and recreational water quality (as measured by microbial indicators) are explored through epidemiological studies. Typically, those epidemiological studies record water quality using one or more indicators and then either compare the illness rates of swimmers and non-swimmers[35] or compare the illness rates of swimmers exposed to one level of measured water quality with those of swimmers exposed to other levels of measured water quality.

Epidemiological studies of illness symptoms among recreational water users have been conducted and reported in scientific research literature for 50 years. In this chapter, we review and summarize the findings of those studies. We also present a closer look at one recent and enormously influential study, the Santa Monica Bay Epidemiological Study. The findings of these studies may be compared with statements about health risks from ocean water contact that are communicated to the public by news reports and initiatives, such as Heal the Bay's beach report cards.

35 For simplicity, the terms "swimmers" and "non-swimmers" are used in this chapter. Swimmers include surfers or anyone engaging in other forms of recreation involving water contact; non-swimmers may have gone to the beach, but stayed out of the water. Several of the published epidemiological studies use the terms "bathers" and "non-bathers" to make the same distinction.

## 1. Three Cautions

Before reviewing those epidemiological studies, we must make three important cautionary statements. All three are important for understanding the findings from the epidemiological studies and for translating studies into public policy.

***Cautions About Swimming-Associated Illness Symptoms***

It is essential to understand that swimmers are more likely than non-swimmers to report illnesses and symptoms such as ear or sinus infections, eye or skin irritations, cough or sore throat, or gastrointestinal upset even when the water to which they were exposed shows no impairment of quality whatsoever. As Cartwright (1992) states, the aquatic environment is not the natural environment of human beings; our bodies are better equipped to shun or shed airborne irritants than waterborne ones. Cabelli and others have observed that swimmers in all variations of water quality report illness symptoms more often than non-swimmers. Similarly, a 1994 World Health Organization report cited by Pruss (1998) "suggested that certain symptoms may result from exposure to water itself rather than from microbiological water quality, for example, by irritation or disturbance of the body's defences."

Researchers have attempted to define some manner of "background rate" or level of illness frequency among swimmers that appears to be independent of water quality. Establishing this background rate allows the researcher to identify illness occurrences that surpass the background rate for swimmers as "excess" illnesses (i.e., above what swimmers would have been expected to experience anyway). When excess illnesses appear, their occurrence and magnitude can be compared with water-quality measures to investigate correlations between water quality and health effects.

This issue is important not only to understand the scientific research literature, but also to understand how there could be so many anecdotal accounts of illness symptoms among recreational water users, even when associations with indicators of water pollution have sometimes appeared to be weak, mixed, or nonexistent. Swimmers, surfers, and others engaged in water recreation do, indeed, experience respiratory and gastrointestinal illness symptoms more often than their land-bound counterparts. This experience understandably translates into a concern or suspicion that "something in the water" is causing the difference. Still, even though there is no reason to doubt any swimmer's or surfer's accounts of illness symptoms following water contact, simple comparisons of swimmers with non-swimmers cannot tell us all we need to know to draw inferences about water quality and health effects.

***Cautions about Epidemiological Studies***

Epidemiological studies are used to inform public-policy decisions on nearly every imaginable topic, including public health.[36] Epidemiological studies compare groups or populations that are similar on some characteristics and differ on others to try to isolate and identify differences that correlate in ways that suggest linkages or relationships (i.e., that "co-vary").

Epidemiological studies are vital to exploring connections between individual or environmental characteristics on the one hand and health or behavioral outcomes on the other. Depending on the study design, the variables being considered, and the data collected, epidemiological studies can even identify an exposure-response relationship in which the degree of exposure to some

36 Although the word "epidemiological" ordinarily connotes an inquiry into health or illness, a study may be called an epidemiological study even when its focus is not overtly health-related. For instance, a recent well-publicized study observed the behavior of kindergartners who had previously attended full-time day care or been cared for primarily by someone other than their mothers as well as kindergartners who had been cared for primarily by their mothers, and reported findings that 18 percent of the former group exhibited aggressive behavior compared with 6 percent of the latter group. This was also referred to as an "epidemiological study" because of its design — comparing two groups similar on some characteristics but differing on others (Stolberg, 2001).

environmental element correlates with the frequency or severity of reaction. Such studies are especially useful to the establishment of risk-based regulations or guidelines (Kay and Dufour, 2000).

Two cautions about epidemiological studies are important. First, epidemiological studies are designed to inquire about associations or correlations between variables, not cause-and-effect linkages. In the context of studies of illness, this means distinguishing between epidemiology and etiology. Epidemiology is the study of the incidence and spread of illness in a population, while etiology is the inquiry into how exactly (i.e., by what process or processes) a particular pathogen stimulates an illness response. Essential as they are, epidemiological studies do not describe the etiology of a disease.

Understanding this limitation is important for keeping epidemiological study findings in perspective and for keeping criticisms of epidemiological studies in perspective. Those who would react to epidemiological evidence by saying that "it does not prove cause and effect" are faulting epidemiology for failing to do something that it cannot do.

A second caution is that some kinds of epidemiological studies cannot be designed or performed as randomized, controlled double-blind experiments due to ethical considerations. Most or all of us were taught in science class that the research design best suited to isolating and identifying relationships between variables and ruling out other factors is the prototypical randomized controlled experiment. Some epidemiological studies can be designed in this fashion, but not all. When researchers are interested in the health effects of exposure to some suspected environmental health risk (e.g., breathing polluted air, swimming in polluted water, etc.), researchers may not be allowed to randomly assign human subjects to varying degrees of exposure without their consent. The protection of human subjects in research studies has been institutionalized in universities and as a condition for government research funding — simply put, researchers may not be allowed to conduct such a study even if they wanted to.

Ethical limitations such as consent requirements make it essentially impossible to implement a "double blind" research design (i.e., one where neither the researchers nor the subjects know who is in the experimental group and who is in the control group). Randomized controlled trials that stop short of a double-blind design are possible, however. British research teams led by Fleisher and Kay recruited subjects and then randomly assigned them to swimmer and non-swimmer groups with pre- and post-exposure medical examinations.

More often, epidemiological studies that involve exposure to health risks are conducted in two other ways. A prospective cohort study design means that the subjects are identified for the study prior to or at the time of exposure to the hazard but before any illness symptoms have been reported or measured. Researchers identify a cohort of subjects who were or are exposed to the hazard in question, and a cohort of subjects not exposed. Follow-up examinations or interviews with the subjects in both cohorts are then conducted to collect the data on illness symptoms, which is then compared and analyzed to assess differences between the cohorts.

Otherwise, a retrospective cohort design is used, where subjects are identified after exposure. For a recreational water-quality study, individuals may be contacted and asked whether and how many times they have swam in the previous week or two as well as asked about their health. Reports of illness symptoms among those who have been swimming during the period are then compared with the reports of those who have not.

The reliance upon non-experimental designs does not mean that credible epidemiological studies cannot be done or that some designs are not better than others (Kay and Dufour, 2000). But there are two important implications. First, epidemiological studies involving the exposure of human subjects to suspected hazards cannot rule out all confounding factors — there will always be the possibility that some characteristic of the experimental group members (other than their exposure to the hazard) produced their greater or lesser rates of illness. Second, criticisms of epidemiological studies on this score can also be unfair — criticizing an epidemiological study for failing to employ a textbook-style experimental design amounts to criticizing the researchers for failing to do something that ethical (and in many cases, institutional) rules may not allow them to do.

***Caution about Translating Epidemiological Evidence into Regulatory Standards***

Comments that regulations should be "based on science," "based on good science," or "based on the best available science" are made and repeated frequently, and few would argue the opposite position (if a rational opposite position can even be imagined). But the advocacy of science-based regulation can lull us into the belief that regulatory standards might somehow be derived directly from the results of scientific research. That belief is an illusion.

As water-quality epidemiologist Victor Cabelli (1979) explained, even the most valid and reliable epidemiological research yielding the most precise findings will not tell us where to set regulatory standards. The setting of standards will remain a policy judgment based on multiple considerations, such as social values and financial consequences.

This general point might be better conveyed with a hypothetical example relevant to our project. Suppose a well-designed epidemiological study, or the combined findings of more than one study, yielded an exposure-response curve showing that excess gastrointestinal symptoms (i.e., above the background rate) occur at an increasing rate as *Enterococcus* concentrations rise above 100 organisms per 100 mL. Statistical tests of significance demonstrate that the correlation represented by that curve is almost certainly not the result of chance or error, and variance measures show that the *Enterococci* variable explains most of the variation in gastrointestinal illness symptoms among swimmers exposed to water of varying quality. The study findings predict five excess illness occurrences at 200 *Enterococcus* organisms per 100 mL, 15 at 300 organisms per 100 mL, 40 at 400 organisms per 100 mL, and 100 at 500 organisms per 100 mL.

In short, our hypothetical example presents data that are as good as epidemiological studies are likely ever to produce (and far better than most actual studies do). Now, the question is: where should the *Enterococci* standard for recreational water quality be set? The obvious answer is: it depends. It depends on whether social values and economic analyses suggest that one excess illness is too many, or five or 15, or 40, or 100, or something higher or in-between. It depends on the sources of the *Enterococci* concentrations, the steps that have to be taken to keep *Enterococci* readings below 500, or 400, or 300, or 200, or 100, and the financial consequences of those steps. It depends on the political preferences of the residents, the political will of public officials, and on numerous other factors.

This is not to say that there is no basis for setting standards. Rather, the choice of a standard will be based on more than the findings of scientific research. As Cabelli said, a regulatory standard for a water-quality indicator "is a suggested upper limit for the density of the indicator in the water which is associated with health risks which are considered unacceptable. *The concept of acceptability implies there are social, economic, even political as well as medical inputs to its derivation* and that these may vary in time as well as space" (Cabelli, 1979, emphasis added).

That is not only as it must be, it is as it should be. Scientific research can, under some circumstances, identify statistical risks. Scientific research, no matter how precise, can never answer the question of whether an identified level of risk is acceptable or unacceptable. Scientific research can be considered when setting regulatory standards. It cannot set them.

Readers are cautioned that although the remainder of this chapter summarizes 50 years of studies on recreational water quality and health risks and specifically analyzes the findings of the Santa Monica Bay Epidemiological Study, it will not answer questions such as whether the AB 411 water-quality standards are right or wrong — or are too strict or too lax — for the protection of public health and the prosperity of coastal communities. That is a social judgment — a matter of policy.

## 2. Review of Epidemiological Literature on Recreational Water Quality and Health Effects

Studies on the health effects of recreation in waters of varying quality and on the usefulness of various water-quality indicators in signaling health risks have been conducted since at least 1948 and have been published in scientific journals since 1953. In this section, we present a review of that literature in two parts: first, a chronological synopsis of some of the studies in that accumulation of published research; second, a presentation of the findings of Pruss' (1998) recently published meta-analysis[37] of 22 epidemiological studies on recreational water exposure and health effects.

### *Chronological Synopsis*

The following chronological synopsis presents brief summaries of major studies conducted on recreational water quality and health effects.

- Stevenson (1953) reported on studies done by the U.S. Public Health Service in the late 1940s and early 1950s. Those studies used TC as an indicator of recreational water quality and followed subjects at selected fresh water locations to determine differential rates of illness between swimmers and non-swimmers. Stevenson reported statistically significant differences in illness rates between swimmers and non-swimmers, and a correlation between TC densities and the illness rates of swimmers.
- The British Public Health Laboratory Service (1959) conducted an extensive retrospective study from 1953 to 1959 of health effects from swimming in sewage-contaminated coastal waters. Specifically, they looked for incidences of polio and enteric fever. They found no statistically significant difference in polio or enteric illness between swimmers and non-swimmers. They also found no significant relationship between the illness rates of swimmers and water quality, although they did not have water-quality measures available for the days their subjects were exposed (see Kay and Dufour, 2000).
- Moore (1959) reported on a comparison between children with poliomyelitis and children without the disease to see whether the groups differed in likelihood or frequency of swimming shortly before the onset of symptoms among the children with polio. He found no statistically significant difference between the groups with different frequency of swimming during the 3 weeks prior to the onset of symptoms.
- D'Alessio et al. (1981) reported on their retrospective study investigating and comparing the swimming histories of children with and without enterovirus. They found evidence of enteroviral disease (symptoms or virus shedding) 3.4 times more frequently among children who swam exclusively at beaches, compared with non-swimmers. The frequency of enteroviral illness among children under the age of four was 10.6 times greater than in non-swimming children of the same age group.

37 A "meta-analysis" is an effort to characterize the information and results from a number of separately reported previous studies relating to a topic.

- Victor Cabelli and Alfred Dufour conducted large-scale studies for the U.S. Environmental Protection Agency from 1972 through 1978. Cabelli studied marine recreational exposure; Dufour studied fresh water exposure. Study design included recruitment on the beach, classification of subjects by the extent of their water exposure, and follow-up interviews 7 to 10 days later. The water they swam in was tested for a range of indicator organisms. Cabelli found that the risk of gastrointestinal illness symptoms rose with the mean *Enterococcus* density of the water. The data depicted a linear relationship of indicator density and illness likelihood.
- Numerous studies of the same type (sometimes called Cabelli studies) were conducted during the 1980s in several other locations around the world. Seyfried et al. (1985a,b) and Lightfoot (1989) conducted fresh water studies in Canada. Fattal et al. (1987) conducted marine water studies in Israel. Ferley et al. (1989) conducted fresh water studies in France. Cheung et al. (1990) conducted marine water studies in Hong Kong. Study teams for the World Health Organization (1994) and the United Nations Environmental Programme conducted marine water studies in Spain and Israel. Fewtrell et al. (1992), Pike (1994), and van Dijk et al. (1996) conducted marine water studies in Britain, Corbett et al. (1993) in Australia, Bandaranyake et al. (1995) in New Zealand, and the Medical Research Council (1995) in South Africa. These studies produced a mix of findings, which is likely the result of the variety of water-quality indicators, illness symptoms, and water environments they examined. Some studies found significant relationships between indicator concentrations and illness rates; others found no such relationship or achieved mixed results (e.g., Seyfried et al., 1985; Cheung et al., 1990).
- Dewailly et al. (1986) studied a group of windsurfers and found them 5.5 times more likely to experience gastrointestinal illness symptoms than other beachgoers at the same estuarine location.
- Study teams led by Fleisher and Kay conducted randomized controlled trials in Britain comparing swimmers and non-swimmers, and comparing swimmers in differing levels of water quality in marine waters. These studies stand out for their design, which attempted to replicate experimental conditions in a field setting (Fleisher et al., 1996; Kay et al., 1994). Their studies reported statistically significant relationships between *Enterococci* densities and rates of gastrointestinal illness. Other bacterial indicators did not show significant relationships with illness rates. A second study, however, found a significant dose-response effect between *Enterococcus* densities and respiratory illness with fever, and between FC densities and ear ailments (Fleisher et al., 1996).
- Haile et al. (1996) conducted a large-scale study of swimmers and non-swimmers in Santa Monica Bay in Southern California. Walk-up contacts were made with 15,492 subjects at the beaches and 13,278 follow-up phone surveys were conducted with those who had been immersed completely in the water. The focus of this study was on water quality as affected by storm-drain flows, so water-quality (as measured by TC, FC, and *Enterococci*) was recorded at various distances from storm-drain outlets. This study is reviewed in greater detail later in this chapter.

***Pruss' Meta-Analysis of the Epidemiological Studies***

Recently, Annette Pruss of the World Health Organization reviewed 22 studies of health effects from recreational water exposure, including most of the ones listed above. Her review was motivated by the World Health Organization's interest in developing advice to countries considering the development and adoption of water-quality guidelines for recreational water. Her analysis was published in the *International Journal of Epidemiology* (Pruss, 1998).

Pruss selected and examined these 22 studies[38] for the information they could contribute to three questions:

- Whether there appears to be a dose-response relationship between recreational water quality and adverse health effects.
- Whether there is some threshold value of bacterial indicator densities above which adverse health outcomes are more likely to occur.
- Whether the severity of illness symptoms varies with recreational water quality as measured by microbial indicators.

The studies that Pruss reviewed used microbial indicators such as those discussed in Chapter Four to measure recreational water quality — most commonly *Enterococci*, FC, and *E. coli*. Eleven of the studies used water-quality measures taken at the time of exposure, and the other 11 used seasonal water-quality means for the locations studied. Fifteen of the 22 studies were conducted in marine recreational water, six in fresh water, and one study included both types. Four of the studies had been conducted in the United States, five in Britain, two in Canada, two in Hong Kong, two in Israel, two in Spain, and the remainder in Australia, Egypt, France, New Zealand, and South Africa. Two of the 22 studies were retrospective, two were randomized, and the remaining 18 were prospective. All 22 studies controlled for confounding factors such as differences among subjects in age, sex, medical history, food and drink intake, other recreational water activities, and sun exposure, with 12 of the studies controlling for one or two such factors, four studies controlling for three or four factors, and six studies controlling for seven or more factors (Pruss, 1998).

Acknowledging some of the cautions noted above, Pruss also separately analyzed the studies comparing swimmers and non-swimmers and the studies comparing swimmers in relatively unimpaired water with swimmers in degraded water. Because swimmers and non-swimmers may differ on other characteristics, Pruss observed, it is worth considering separately those health-effects studies that compared swimmers with other swimmers where the principal variation was the measured microbial water quality.

Pruss' meta-analysis of the 22 studies found the following (1998):

- Nineteen of the 22 studies found statistically significant relationships between bacterial indicator counts and the rates of gastrointestinal illness symptoms. Three of the 22 studies found no significant relationships between illness rates and bacterial indicators.
- Most of the statistically significant relationships were between indicator densities and gastrointestinal illness symptoms. Only a few studies reported associations between indicator densities and non-gastrointestinal symptoms. One study found a significant positive relationship between FC densities and gastrointestinal illness, but a negative relationship between FC counts and eye and ear infections.
- Four of the studies that found significant relationships between indicator densities and gastrointestinal illness rates found that illness rates were higher among exposed children than adults.
- Relative risks could be calculated from the data in studies comparing illness rates of swimmers and non-swimmers. For gastrointestinal symptoms, the relative risks were all between

38 Pruss began with 36 published studies, but excluded those with insufficient documentation to address the questions she was interested in, those in which the sample size was too small to draw definitive conclusions in which the response rate of subjects in follow-up evaluations had been below 50 percent, or those that only compared swimmer and non-swimmer illness rates without including measures of water quality (Pruss, 1998).

1.0 and 2.5, meaning that swimmers were never less likely than non-swimmers to experience gastrointestinal symptoms and were as much as 2.5 times more likely to do so.

- Relative risks could also be calculated from the data in studies comparing illness rates of swimmers in poorer quality water with swimmers in better quality water (as measured by bacterial indicators). For gastrointestinal symptoms, the relative risks ranged from 0.5 to 3. One study reported lesser symptoms in poorer quality water, four studies reported approximately the same risk of illness (i.e., relative risk of approximately 1.0), and most studies found that swimmers in poorer quality water had higher risks of illness symptoms and that the rates were as much as 3 times greater than for swimmers in better quality water.
- Seven studies (Cabelli, United States, 1982; Cabelli, Egypt, 1983; Fattal et al., 1987; World Health Organization, 1994; Kay et al., 1994; Bandaranayake et al., 1995; Medical Research Council, 1995) involved *Enterococci* densities in marine recreational water and swimmers who were completely immersed in the water. In all 29 cohort comparisons in those seven studies, swimmers exposed to water with higher *Enterococcus* densities had the same or higher rates of gastrointestinal illness than swimmers exposed to water with lower *Enterococcus* densities. Illness rates in those studies ranged from 16 to 221 incidences per 1,000 swimmers among those exposed to poorer-quality water.
- One study (Cheung et al., 1990) involved *E. coli* densities in marine recreational water and swimmers who were completely immersed. In three of six cohort comparisons reported in the Cheung et al. (1990) study, swimmers in poorer quality water (as measured by *E. coli* densities) actually had lower rates of gastrointestinal illness symptoms than swimmers in better water. These results may say more about the weaknesses of *E. coli* as a water-quality indicator in the marine environment than they do about the water-quality health effects linkage.
- In addition to *Enterococci*, staphylococci showed correlations with swimmer illness rates, although staphylococci were included in fewer of the studies. As noted in Chapter Four, staphylococci were more often associated with ear, skin, and respiratory illness symptoms, and are assumed to be associated with the number of swimmers at a particular location.
- Examining the regression relationships that could be estimated between illness rates and indicator densities, Pruss (1998) concluded, "many studies suggest continuously increasing risk models." In short, illness rates tended to rise with bacterial indicator concentrations.
- With respect to the question of threshold levels of water quality beyond which significant illness rate disparities appear, Pruss (1998) concluded the following: "Most of the suggested thresholds are low compared to water qualities often encountered in coastal waters of recreational use. They range from only a few indicator counts per 100 mL to about 30 counts per 100 mL, and were higher for Egypt and Hong Kong (around 100 to 200 indicator counts per 100 mL)."
- The only randomized controlled trial relating swimmer exposure, water quality, and gastrointestinal illness symptoms (Kay, 1994) "reported a stronger relationship between exposure and gastroenteric symptoms than other studies . . . The same also applies to Fleisher's [et al., 1996] randomized controlled trial investigating non-enteric illnesses" (Pruss, 1998).
- The studies did not yield any generalizable findings concerning the question of water quality and illness severity.

Pruss concluded her meta-analysis with two sets of observations. Her first observations summarized the weaknesses and possibilities for error in several of the studies. These weaknesses had primarily to do with the use of water-quality indicators of questionable precision (e.g., FC, TC, and *E. coli* in marine water), the use of seasonal water quality means rather than time-of-exposure measures of water quality in some studies, the inability of bacterial indicators to detect the presence of viruses and other etiological agents and, in some cases, the reliance upon self-reported recall of illness symptoms by swimmers rather than medical examinations. Although all of these weaknesses cast doubt upon the precision of the findings, Pruss notes that they do not provide a basis for concluding that the studies have systematically overestimated or underestimated the health effects of recreational water exposure — all of the error sources leave open the possibility that the risks of recreational water contact are greater than the studies reported, as well as the possibility that the risks are lesser than the studies reported.

Her second observations had to do with the question of causality. She listed the set of nine criteria proposed by Bradford Hill for establishing causality from environmental epidemiological evidence, then applied the cumulative body of evidence from the 22 studies to those nine criteria. She found seven of the nine criteria fulfilled by that body of evidence:

- Strength of association.
- Consistency (of observations across locations and times).
- Temporality (exposure occurs prior to health effects).
- Biological gradient (i.e., a dose-response or exposure-response effect can be discerned).
- Plausibility (a logical connection between suggested agent and hypothesized effect).
- Coherence (the evidence does not conflict with other knowledge about the disease in question).
- Analogy (in this case, the evidence is similar to the relationship known to exist between contaminated drinking water and gastrointestinal illness) (Pruss, 1998).

The two criteria of causality that were not supported by evidence from the 22 studies were specificity of association and preventability. Specificity of association could not be assured because of the possibilities that other etiological agents could be present. The criterion of preventability means that one can interrupt (at least, in experimental settings) the exposure-to-illness pathway and affect the illness outcome. As Pruss (1998) pointed out, experiments on preventive actions and health outcomes have not yet been reported.

### 3. The Santa Monica Bay Epidemiological Study

The Santa Monica Bay Epidemiological Study has been called a "landmark"[39] and "unprecedented"[40] study of beach water-quality public health risks. Sponsored by the Santa Monica Bay Restoration Project, a nonprofit coalition of state, local, and federal government agencies, environmental advocacy groups, and local (Southern California) interests, it focused (apparently, for the first time) on the relative risk of illnesses caused by dry weather storm-drain flows.[41] When it was released, the study received considerable media attention and continues to be authoritatively cited in popular and academic discussions of beach safety. The results of the Santa Monica Bay Epidemiological Study significantly affected California's recreational water-quality standards promulgated pursuant to AB 411, and have affected regional and local water-quality control efforts throughout Southern California.

Designed as a cohort or "Cabelli" study, the Santa Monica Bay Epidemiological Study tracked the health histories of swimmers who were exposed to ocean water at three Los Angeles County beaches subject to continuous dry weather outfall flows:

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39 U.S. Environmental Protection Agency Office of Wetlands, Oceans and Watersheds, How Safe is it to Swim in Santa Monica Bay? Epidemiology Study Assesses Health Risks, www.epa.gov/docs/OWOW/estuaries/coastlines/coastlines6.3/monicbay.html.

40 J. Rainey, "Bay Study Links Drain Outlets, Swimmer Illness," *Los Angeles Times*, Page 1, May 7, 1996.

41 Santa Monica Bay Epidemiological Study at 7 ("At the time this study began, there had never been an epidemiologic study of persons who swam in the marine waters contaminated by heavy runoff waters").

- Malibu, where upstream waters draining the Malibu Creek watershed, including effluent from a major sewage treatment facility, collect in a beachfront lagoon that discharges into a popular surfing beach.
- Will Rogers, where an underground storm-drain system channels upstream waters from high-end residential and undeveloped open space to a beachfront outfall.
- Ashland, where a storm-drain outfall discharges runoff originating largely from developed portions of urban Santa Monica.

The Santa Monica Bay Epidemiological Study was conducted during summer 1995. The research team was deployed along each of the three beaches to interview all eligible swimmers and to take ankle-deep water grab samples at seven specific locations:

- 400 yards or more upcoast from the storm-drain location.
- 400 yards or more downcoast from the storm-drain location.
- 51 to100 yards up-coast from the storm drain.
- 51 to 100 yards down-coast from the storm drain.
- 1 to 50 yards up-coast from the storm drain.
- 1 to 50 yards down-coast from the storm drain.
- Directly at the storm-drain outfall.[42]

Nine to 15 days after the initial interviews were conducted, the swimmers were recontacted by telephone. Provided certain guidelines were met (including no additional marine water submersion in the interim period), the swimmers were queried about specific symptoms of illness, such as coughing, fever, rashes, sore throat, or stomach pain.

Reports of 16 symptoms were individually tabulated. The Santa Monica Bay Epidemiological Study also grouped the survey into reports of three co-occurring symptom complexes:

- Highly credible gastrointestinal illness 1 (HCGI1), comprised of vomiting, diarrhea and fever, or stomach pain and fever, a definition that corresponds with the U.S. Environmental Protection Agency's definition of "highly credible" gastrointestinal disease.
- Highly credible gastrointestinal illness 2 (HCGI2), which was restricted to co-occurrences of vomiting and fever.
- Significant respiratory disease (SRD), which is co-occurrences of either fever and nasal congestion, fever and sore throat, or coughing with phlegm.

The reported results for the approximately 11,000 qualifying swimmers analyzed by the Santa Monica Bay Epidemiological Study for each study point are presented in Table 5.1.

The data show, for example, that in the 3,030-member control group — swimmers who entered the water more than 400 yards from the storm-drain outfall — there were 138 reported cases of fever, 26 cases of HCGI2, and 139 cases of SRD during the period of 9 to 15 days after swimming. The corresponding results for the 827 swimmers who bathed at the drain were 59, 15, and 63 cases of illness, respectively.

The Santa Monica Bay Epidemiological Study treated the results for swimmers more than 400 yards to either side of the flowing outfall as the unexposed "control," or the baseline standard for illness incidence that would be expected to occur from causes other than adverse water quality. The results for all other study points were compared with the control group in two ways: (1) by calculating excess or "attributable" cases of illness at each study point

42 Southern California beaches are generally situated north-south along the coast and are subject to currents running from the north. "Upcoast" in the Santa Monica Bay Epidemiological Study was north of the drain point and, in most circumstances, prevailing currents would tend to sweep drain discharges to the southern "downcoast" locations.

*Table 5.1* Santa Monica Bay Epidemiological Study
Actual Unadjusted Sampling and Illness Reports, All Locations Combined

| Illness | Controls (400+ Yards Upcoast and Downcoast from Drain) | 51 to 100 Yards Upcoast | 1 to 50 Yards Upcoast | Drain | 1 to 50 Yards Downcoast | 51 to 100 Yards Downcoast |
|---|---|---|---|---|---|---|
| **Total Qualified Interviewees** | 3,030 | 2,186 | 2,592 | 827 | 1,926 | 1,125 |
| **Reported Illnesses** | | | | | | |
| Fever | 138 | 109 | 114 | 59 | 94 | 49 |
| Chills | 72 | 54 | 63 | 31 | 45 | 31 |
| Eye Discharge | 61 | 45 | 50 | 19 | 23 | 14 |
| Earache | 116 | 81 | 81 | 38 | 55 | 35 |
| Ear Discharge | 21 | 10 | 19 | 13 | 6 | 9 |
| Skin Rash | 23 | 20 | 35 | 4 | 18 | 10 |
| Infected Cut | 17 | 10 | 23 | 6 | 14 | 6 |
| Nausea | 133 | 75 | 82 | 40 | 61 | 40 |
| Vomiting | 57 | 40 | 36 | 25 | 27 | 18 |
| Diarrhea | 204 | 96 | 120 | 53 | 82 | 67 |
| Diarrhea with Blood | 7 | 1 | 1 | 2 | 2 | 1 |
| Stomach Pain | 206 | 126 | 163 | 61 | 108 | 68 |
| Coughing | 209 | 164 | 173 | 55 | 123 | 99 |
| Phlegm | 90 | 69 | 80 | 39 | 63 | 45 |
| Nasal Congestion | 273 | 214 | 205 | 74 | 166 | 137 |
| Sore Throat | 190 | 168 | 177 | 59 | 127 | 76 |
| HCGI1 | 102 | 63 | 71 | 35 | 50 | 33 |
| HCGI2 | 26 | 19 | 20 | 15 | 12 | 9 |
| SRD | 139 | 114 | 112 | 63 | 93 | 63 |

*Source: Santa Monica Bay Epidemiological Study (Tables 17 to 21). The study did not report separate results for 400+ yards upcoast and downcoast from the drain. Data from these areas were aggregated into the "unexposed" control group.*

compared with the control group per 10,000 swimmers; and (2) by calculating the "relative risk" (RR) experienced by a swimmer at each study point compared with the control group.[43]

The calculation of excess cases was made by normalizing the incidence of reported illness at each of the seven study points to reflect expected symptoms per 10,000 swimmers. Among 10,000 swimmers in control waters, for instance, the Santa Monica Bay Epidemiological Study data indicated that about 455 swimmers would be expected to have fever and 86 would exhibit HCGI2 symptoms within 9 to 15 days, compared with 713 and 181 per 10,000 swimmers who swam directly at the drain (Table 5.2).

43 The Santa Monica Bay Epidemiological Study performed several assessments of the link between bacterial indicators found in the water grab samples and reported illnesses. Its results were mixed and generally inconclusive, except for data obtained subject to certain limiting conditions, such as a baseline level of TC coupled with a TC-to-FC ratio of a certain level (the study examined ratio cut-points of 2 to 8) ("In general, when we estimated risk ratios using the established cut-points [for bacterial indicators] there were very few positive associations with any single indicator...." Santa Monica Bay Epidemiological Study at 57). The Santa Monica Bay Epidemiological Study ratio information was apparently used in the development of the AB 411 ratio standards, as discussed in Chapter 4 of this report. In general, the RR and excess or attributable case information were more heavily used than bacterial indicator data to communicate the results to the public. The Santa Monica Bay Epidemiological Study emphasized that its findings were particularly robust for distance from the drain (Santa Monica Bay Epidemiological Study at 59).

*Table 5.2* Reported Illnesses at Each Study Point, Normalized to Reflect Incidence per 10,000 Swimmers

| Illness | Controls (400+ Yards Upcoast and Downcoast from Drain) | 51 to 100 Yards Upcoast | 1 to 50 Yards Upcoast | Drain | 1 to 50 Yards Downcoast | 51 to 100 Yards Downcoast |
|---|---|---|---|---|---|---|
| **Scaling Ratio Illness per 10,000** | 3.30 | 4.57 | 3.86 | 12.09 | 5.19 | 8.89 |
| Fever | 455 | 499 | 440 | 713 | 488 | 436 |
| Chills | 238 | 247 | 243 | 375 | 234 | 276 |
| Eye Discharge | 201 | 206 | 193 | 230 | 119 | 124 |
| Earache | 383 | 371 | 313 | 459 | 286 | 311 |
| Ear Discharge | 69 | 46 | 73 | 157 | 31 | 80 |
| Skin Rash | 76 | 91 | 135 | 48 | 93 | 89 |
| Infected Cut | 56 | 46 | 89 | 73 | 73 | 53 |
| Nausea | 439 | 343 | 316 | 484 | 317 | 356 |
| Vomiting | 188 | 183 | 139 | 302 | 140 | 160 |
| Diarrhea | 673 | 439 | 463 | 641 | 426 | 596 |
| Diarrhea with Blood | 23 | 5 | 4 | 24 | 10 | 9 |
| Stomach Pain | 680 | 576 | 629 | 738 | 561 | 604 |
| Coughing | 690 | 750 | 667 | 665 | 639 | 880 |
| Phlegm | 297 | 316 | 309 | 472 | 327 | 400 |
| Nasal Congestion | 901 | 979 | 791 | 895 | 862 | 1,218 |
| Sore Throat | 627 | 769 | 683 | 713 | 659 | 676 |
| HCGI1 | 337 | 288 | 274 | 423 | 260 | 293 |
| HCGI2 | 86 | 87 | 77 | 181 | 62 | 80 |
| SRD | 459 | 522 | 432 | 762 | 483 | 560 |

*Source: Santa Monica Bay Epidemiological Study (Tables 17 to 21). The scaling ratio is the number used to adjust the reported cases in each category to incidents per 10,000. Drain cases were fewest in number, so they are subject to the highest multiple. Because of the multiplying, each reported drain case generates more than 12 cases per 10,000 compared with about three cases for the control group.*

The Santa Monica Bay Epidemiological Study then calculated excess or "attributable" cases for each symptom at each location. This was the net increase or decrease in reported illness per 10,000 swimmers compared with the control group's rate, and was intended to suggest the influence of storm-drain contamination. Table 5.3 suggests that there would be an excess of 258 cases of fever, 303 cases of SRD, and 25 fewer cases of coughing within 9 to 15 days among 10,000 swimmers at the drain compared with a similar number swimming in control waters.

Positive "attributable" case numbers were taken as evidence of adverse storm-drain effects, particularly when the cases exceeded 100 per 10,000 swimmers. The study was primarily designed to identify circumstances in which excess cases per 10,000 exceeded 100 (or 1 excess case per 100):

> In numerous discussions organized by [the Santa Monica Bay Restoration Project], prior to the start of this study, an excess risk of 1 case per 100 exposed was generally considered a noteworthy health risk, so the study was designed to

*Table 5.3* Attributable or Excess Illnesses per 10,000 Swimmers Compared to Controls

| Illness | Controls (400+ Yards Upcoast and Downcoast from Drain) | 51 to 100 Yards Upcoast | 1 to 50 Yards Upcoast | Drain | 1 to 50 Yards Downcoast | 51 to 100 Yards Downcoast |
|---|---|---|---|---|---|---|
| **Scaling Ratio Excess Illness per 10,000** | 3.30 | 4.57 | 3.86 | 12.09 | 5.19 | 8.89 |
| Fever | 0 | 43 | –16 | 258 | 33 | –20 |
| Chills | 0 | 9 | 5 | 137 | -4 | 38 |
| Eye Discharge | 0 | 5 | –8 | 28 | –82 | –77 |
| Earache | 0 | –12 | –70 | 77 | –97 | –72 |
| Ear Discharge | 0 | –24 | 4 | 88 | –38 | 11 |
| Skin Rash | 0 | 16 | 59 | –28 | 18 | 13 |
| Infected Cut | 0 | –10 | 33 | 16 | 17 | -3 |
| Nausea | 0 | –96 | –123 | 45 | –122 | -83 |
| Vomiting | 0 | –5 | –49 | 114 | –48 | –28 |
| Diarrhea | 0 | –234 | –210 | –32 | –248 | –78 |
| Diarrhea with Blood | 0 | –19 | –19 | 1 | –13 | –14 |
| Stomach Pain | 0 | –103 | –51 | 58 | –119 | –75 |
| Coughing | 0 | 60 | –22 | –25 | –51 | 190 |
| Phlegm | 0 | 19 | 12 | 175 | 30 | 103 |
| Nasal Congestion | 0 | 78 | –110 | -6 | –39 | 317 |
| Sore Throat | 0 | 141 | 56 | 86 | 32 | 48 |
| HCGI1 | 0 | –48 | –63 | 87 | –77 | –43 |
| HCGI2 | 0 | 1 | –9 | 96 | –24 | –6 |
| SRD | 0 | 63 | –27 | 303 | 24 | 101 |

*Source: Calculated from the Santa Monica Bay Epidemiological Study (Tables 17 to 21).*

> detect this level of risk (of course, the relative magnitude of these risks compared with other health risks will be a matter of judgment by interested parties).[44]
>
> At meetings organized by the [Santa Monica Bay Restoration Project] prior to the start of the study (and attended by senior scientists who were to direct the study, Santa Monica Bay Restoration Project staff and technical advisers, and public health practitioners from the L.A. County Department of Health Services) an excess risk of 1 case per 100 exposed subjects was identified by verbal consensus as "noteworthy."[45]

The Santa Monica Bay Epidemiological Study also calculated the RR of illness at various locations compared with the unexposed control data for swimmers more than 400 yards from the drain. The reported incidence per 10,000 swimmers for each location was divided by the

44 Santa Monica Bay Epidemiological Study at 68.

45 Santa Monica Bay Epidemiological Study at 50.

control group's reported incidence.[46] The resulting ratio was intended to suggest the increased or decreased risk of a swimmer developing a symptom attributable to contaminated runoff exposure from the drain (Table 5.4).

*Table 5.4* Unadjusted RR Ratios:
Illness per 10,000 at Various Sample Points Compared with Illness per 10,000 Among Controls

| Illness | Controls (400+ Yards Upcoast and Downcoast from Drain) | 51 to 100 Yards Upcoast | 1 to 50 Yards Upcoast | Drain | 1 to 50 Yards Downcoast | 51 to 100 Yards Downcoast |
|---|---|---|---|---|---|---|
| Fever | 1.00 | 1.09 | 0.97 | 1.57 | 1.07 | 0.96 |
| Chills | 1.00 | 1.04 | 1.02 | 1.58 | 0.98 | 1.16 |
| Eye Discharge | 1.00 | 1.02 | 0.96 | 1.14 | 0.59 | 0.62 |
| Earache | 1.00 | 0.97 | 0.82 | 1.20 | 0.75 | 0.81 |
| Ear Discharge | 1.00 | 0.66 | 1.06 | 2.27 | 0.45 | 1.15 |
| Skin Rash | 1.00 | 1.21 | 1.78 | 0.64 | 1.23 | 1.17 |
| Infected Cut | 1.00 | 0.82 | 1.58 | 1.29 | 1.30 | 0.95 |
| Nausea | 1.00 | 0.78 | 0.72 | 1.10 | 0.72 | 0.81 |
| Vomiting | 1.00 | 0.97 | 0.74 | 1.61 | 0.75 | 0.85 |
| Diarrhea | 1.00 | 0.65 | 0.69 | 0.95 | 0.63 | 0.88 |
| Diarrhea with Blood | 1.00 | 0.20 | 0.17 | 1.05 | 0.45 | 0.38 |
| Stomach Pain | 1.00 | 0.85 | 0.92 | 1.08 | 0.82 | 0.89 |
| Coughing | 1.00 | 1.09 | 0.97 | 0.96 | 0.93 | 1.28 |
| Phlegm | 1.00 | 1.06 | 1.04 | 1.59 | 1.10 | 1.35 |
| Nasal Congestion | 1.00 | 1.09 | 0.88 | 0.99 | 0.96 | 1.35 |
| Sore Throat | 1.00 | 1.23 | 1.09 | 1.14 | 1.05 | 1.08 |
| HCGI1 | 1.00 | 0.86 | 0.81 | 1.26 | 0.77 | 0.87 |
| HCGI2 | 1.00 | 1.01 | 0.90 | 2.11 | 0.73 | 0.93 |
| SRD | 1.00 | 1.14 | 0.94 | 1.66 | 1.05 | 1.22 |

*Source: Calculated from the Santa Monica Bay Epidemiological Study (Tables 22 to 23).*

The RR data suggest that swimmers at the drain are 227 percent (about 2.3 times) more likely to experience an ear discharge and 211 percent more likely to exhibit HCGI2 symptoms than those in control waters. In contrast, swimmers within 1 to 50 yards either side of the drain would be 6 percent more likely (upcoast) to 55 percent *less likely* (downcoast) than the control group to experience an ear discharge, and about 10 percent (upcoast) to 27 percent *less likely* (downcoast) to experience HCGI2 symptoms.

Cabelli-type cohort studies often focus on co-reported symptom clusters rather than isolated individual symptoms to reduce the likelihood of respondent error and indicate more serious,

46 The Santa Monica Bay Epidemiological Study amplified these statistics by calculating 95-percent confidence intervals and by performing certain modeling exercises. The data were also adjusted in the May 1996 report to account for demographic and other variations among the respondents, and again in the published 1999 summary of the study. These adjustments primarily appeared to affect reported incidences of SRD, but otherwise did not appreciably vary from the unadjusted ratios presented in the 1996 study (Table 5.4).

credible health risks. Figure 5.1 presents the excess cases of HCGI1, HCGI2, and SRD symptom clusters reported along the 800-yard range of the Santa Monica Bay Epidemiological Study area. It shows that excess illness reports for the three co-occurrence symptom clusters — SRD, HCGI1, and HCGI2 — were significantly higher directly at the drain; however, HCGI1 and HCGI2 excess case reports were below the control levels (and the lowest for all sample areas) in the up- and downcoast 1-to-50 yard ranges. SRD excess cases were reported at non-drain locations and higher in the 51-to-100 yard ranges than in the 1-to-50 yard study interval (Figure 5.1).[47]

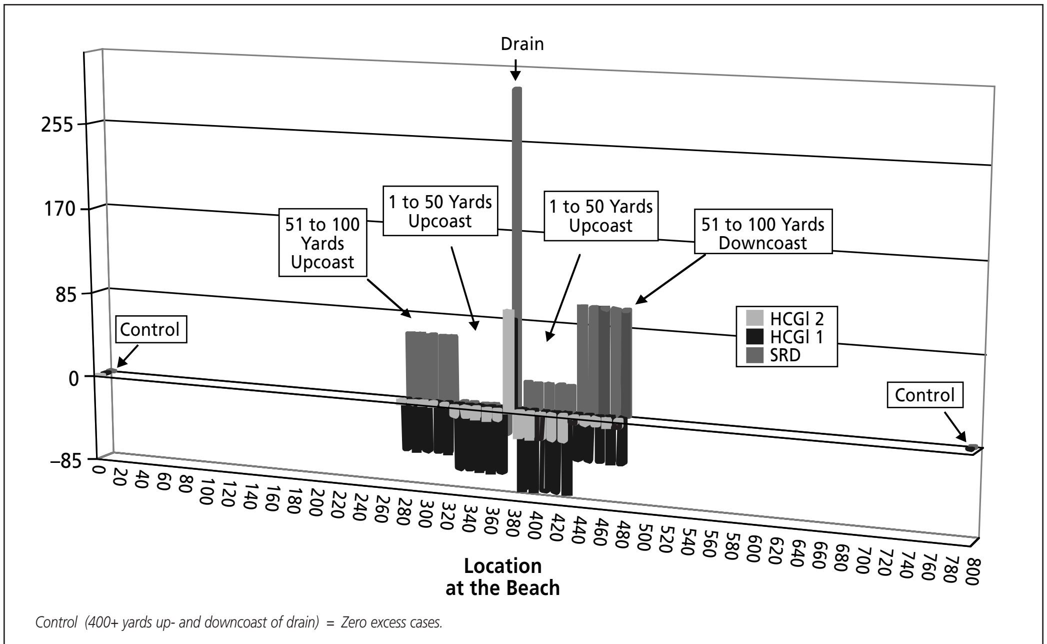


*Figure 5.1.* Representation of Santa Monica Bay Epidemiological Study excess cases per 10,000 swimmers by sample location for the HCGI1, HCGI2, and SRD symptom clusters.

Similarly, RR ratios for each of the three symptom clusters also strongly peaked directly at the drain, were generally close to or lower than control levels in the 1-to-51 yard ranges, and were slightly elevated for SRD primarily in the 51-to-100-yard ranges (Figure 5.2).

Finally, it is worth noting that most of the individual symptom and co-occurrence results in the Santa Monica Bay Epidemiological Study were not considered statistically significant by the research team. With a couple of exceptions, statistically significant results occurred only among the swimmers who swam directly in front of the drain (Table 5.5).

As a result, when the study sponsors requested a summary assessment of health risks, the research team analyzed only the five reported incidences of statistically significant single symptoms at the drain — fever, chills, ear discharge, coughing with phlegm, and vomiting — and the two statistically significant reports of symptom co-occurrences at the drain — SRD and HCGI2. Corrected for multiple symptom reports, the Santa Monica Bay Epidemiological Study calculated the likelihood that respondents at the drain would report excess cases of:

47 The Santa Monica Bay Epidemiological Study did not systematically explore the reasons why excess disease reports would be lowest in the areas immediately contiguous with the drain. It did suggest that the controls might be contaminated and that the true risk distribution was, consequently, skewed. When the "exposed" cases were compared to control results obtained when the TC-to-FC ratio was greater than 5 (approximately 600 of the 3,000 member control group), the results for the zero-to-100-yard ranges on either side of the drain generally rose, but the 1-to-51-ranges still tended to be lower. Santa Monica Bay Epidemiological Study (Tables 24 to 30).

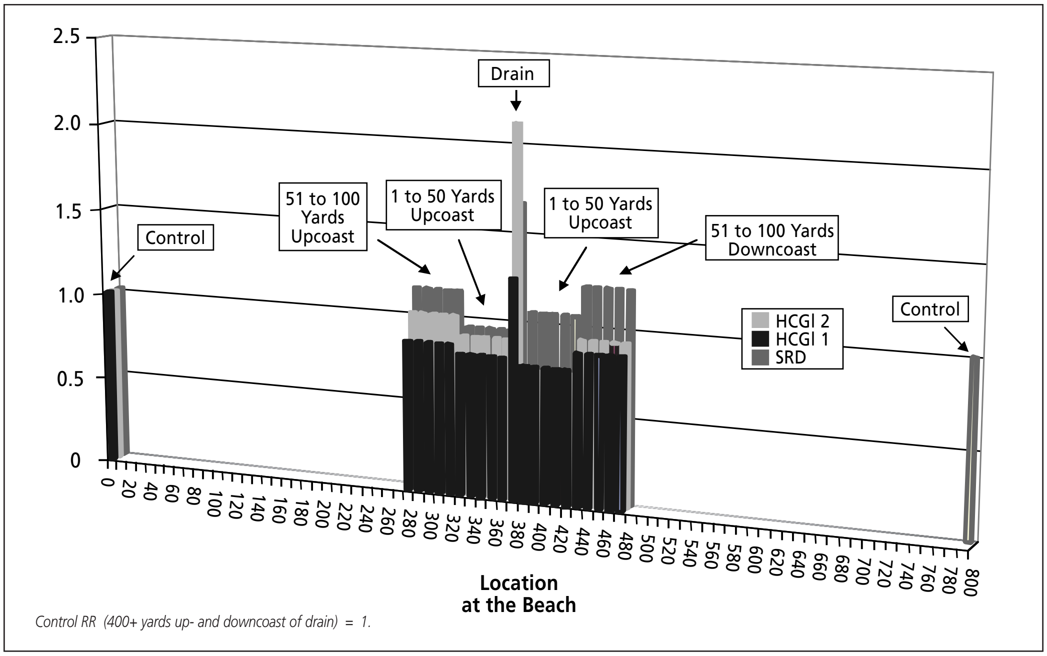


*Figure 5.2.* Representation of Santa Monica Bay Epidemiological Study RR ratios by sample location for the HCGI1, HCGI2, and SRD symptom clusters

*Table 5.5* Results Identified by Santa Monica Bay Epidemiological Study Researchers as Statistically Significant

| Illness | Controls (400+ Yards Upcoast and Downcoast from Drain) | 51 to 100 Yards Upcoast | 1 to 50 Yards Upcoast | Drain | 1 to 50 Yards Downcoast | 51 to 100 Yards Downcoast |
|---|---|---|---|---|---|---|
| Fever | 0 | 43 | –16 | 258* | 33 | –20 |
| Chills | 0 | 9 | 5 | 137* | –4 | 38 |
| Eye Discharge | 0 | 5 | –8 | 28 | –82 | –77 |
| Earache | 0 | –12 | –70 | 77 | –97 | –72 |
| Ear Discharge | 0 | –24 | 4 | 88* | –38 | 11 |
| Skin Rash | 0 | 16 | 59* | –28 | 18 | 13 |
| Infected Cut | 0 | –10 | 33 | 16 | 17 | –3 |
| Nausea | 0 | –96 | –123 | 45 | –122 | –83 |
| Vomiting | 0 | –5 | –49 | 114* | –48 | –28 |
| Diarrhea | 0 | –234 | –210 | –32 | –248 | –78 |
| Diarrhea with Blood | 0 | –19 | –19 | 1 | –13 | –14 |
| Stomach Pain | 0 | –103 | –51 | 58 | –119 | –75 |
| Coughing | 0 | 60 | –22 | –25 | –51 | 190* |
| Phlegm | 0 | 19 | 12 | 175* | 30 | 103 |
| Nasal Congestion | 0 | 78 | –110 | –6 | –39 | 317* |
| Sore Throat | 0 | 141 | 56 | 86 | 32 | 48 |
| HCGI1 | 0 | –48 | –63 | 87 | –77 | –43 |
| HCGI2 | 0 | 1 | –9 | 96* | –24 | –6 |
| SRD | 0 | 63 | –27 | 303* | 24 | 101 |

*Significant at probability <0.05 level. *Source: Calculated from the Santa Monica Bay Epidemiological Study (Tables 17 to 21).*

- At least one of the five individual symptoms for which statistically significant excess case results had been found.
- One of the two co-occurrence symptom groups for which statistically significant excess case results had been found.

This assessment suggested there would be about 373 excess cases of at least one of the five single symptoms (RR = 1.44) and about 314 excess cases of either SRD or HCGI2 (RR = 1.54) at the drain compared with the control group.[48]

Since the statistically significant data were clustered directly at the drain, Santa Monica Bay Epidemiological Study researchers emphasized that the risks associated with an exposure to coastal waters could be observed conclusively only for the cohort of swimmers who chose to bathe directly in the flowing outfall effluent:

> We observed differences in risk for a number of outcomes when we compared subjects swimming at zero yards versus 400+ yards. Most of the relative risk suggested an approximately 50-percent increase in risk. Furthermore, as evinced by both the risks and RRs, there is an apparent threshold of increased risk occurring primarily at the drain: *No dose response is evinced with increasing closeness to the drain*, but there is a jump in risk for many adverse health outcomes among those swimming at the drain (Haile et al., 1999, emphasis added).

The Santa Monica Bay Epidemiological Study public information summary also emphasized the link between swimming directly in storm-drain effluent and the study's health risk findings:

> There is an increased risk of illness associated with swimming near flowing storm drain outlets in Santa Monica Bay. Statistically significant increases in risks for a broad range of adverse health effects (fever, chills, ear discharge, vomiting, coughing with phlegm, HCGI-2, and SRD) were found for subjects that swam in front of storm drains (at zero yards) in comparison to those who swam over 400 yards away . . . For example, there was a 57-percent greater incidence of fever for swimmers at the drain than at 400 yards away. *These increases in risk appeared be limited to the zero yards distance, as a significant drop off in effects were observed at other distances upcoast or downcoast from the drain*. . . .[49]
>
> The results of this health risk investigation provide both good news and cause for concern. *The good news is that, of the bay's 50-plus mile coastline, less than 2 miles are problematic.* However, the study has also confirmed that there is a risk of illness associated with swimming in or immediately adjacent to flowing storm drains.[50]

The researchers' presentation of their findings, and the conclusions they drew from their findings, were clearly both limited and qualified. As seen in Chapters 1 and 2, however, claims are frequently made and repeated that the Santa Monica Bay Epidemiological Study "proved" that people who swim "near" storm drains are twice as likely to get sick as people who swim farther away. Furthermore, those claims have been extended to the entire Southern California coastline, and stated so often and so forcefully that they have contributed to the current rush of activity to keep storm-drain runoff from discharging into the ocean.

48 Santa Monica Bay Epidemiological Study Public Information Summary (1996), Addendum.

49 Santa Monica Bay Epidemiological Study Public Information Summary (1996), p. 3.

50 Santa Monica Bay Epidemiological Study Public Information Summary (1996), p. 7, emphasis in original.

### 4. Conclusions

The published scientific research literature on health effects and recreational water quality has accumulated for 50 years now. It is composed of numerous epidemiological studies. Those studies cannot establish cause-and-effect linkages between recreational water quality and illnesses experienced by swimmers and other recreational water users. They do, however, report a substantial and accumulating body of associations and correlations between health risk and water quality from which a few conclusions can be drawn.

First, while there have been studies finding no statistically significant association between illness rates and recreational water quality (as measured by the common bacterial indicators), these are by far outnumbered by the studies reporting such associations. Even the few studies finding no statistically significant relationship are of questionable value for our purposes:

- The British Public Health Laboratory Service studies in the 1950s looked specifically for polio and paratyphoid, and did not have day-of-exposure water-quality data.
- The Seyfried et al. (1985a,b) studies in Canada were in a freshwater environment.
- The Cheung et al. (1990) study in Hong Kong relied on *E. coli* as a water-quality indicator, which has been determined to be a poor indicator for use in salt water.

Second, while statistically significant correlations have been found between water-quality indicator concentrations and illness incidence rates, some indicators show stronger and more consistent correlations than others. In particular, as Chapter 4 suggested, *Enterococci* appear to be better bacterial water-quality indicators than TC and FC in salt water.

Third, while the most commonly used bacterial indicators correlate to varying degrees of success with gastrointestinal illness rates, only *staphylococcus* is associated with any regularity to the range of non-enteric illness symptoms reported by recreational water users (e.g., skin, eye, ear, and respiratory symptoms). *Staphylococcus* is not currently used as part of the regular coastal water-quality monitoring regime in Southern California or anywhere else. Even if it were, it is unclear how staphylococci concentrations would be interpreted and applied to public health protection since staphylococci organisms apparently enter recreational waters primarily as a result of shedding by recreational water users themselves.

Fourth, the Santa Monica Bay Epidemiological Study was one of the largest and most recent studies linking recreational water quality and illness outcomes, but it contains numerous anomalies that question its findings about the relationship between storm-drain proximity and health risks to swimmers. Two groups of swimmers in the Santa Monica Bay Epidemiological Study had the highest rates of highly credible gastrointestinal illness symptoms — those swimming directly in front of a discharging storm-drain and those 400 or more yards away. The swimmers in between those distances (i.e., those within 50 or 100 yards of a storm-drain) were actually less likely to report these and several other illness symptoms than either of the other two groups. Certainly, the Santa Monica Bay Epidemiological Study does not support the claim that is so often made on its behalf: that those swimming “near” storm-drains are more likely to become ill than those swimming farther away.

Fifth, the associations between water-quality indicators and illness rates of recreational water users had been established in several studies well before the Santa Monica Bay Epidemiological Study was conducted and reported. For instance, the often-reported finding from the Santa Monica Bay Epidemiological Study of some swimmers being “twice as likely” to become sick as others can be found in the Cabelli, Fattal, Bandaranayke, and Kay studies, which correlate the relative risk with water-quality measures at least as strongly as the Santa Monica Bay Epidemiological Study. The Santa Monica Bay Epidemiological Study provided neither the first nor apparently the strongest support in the research literature for a coastal water-quality monitoring regime based on frequent measurements of *Enterococci* densities.

Why then is the Santa Monica Bay Epidemiological Study so often cited, and why has it been relied upon so strongly for everything from the AB 411 water-quality guidelines to the Heal the Bay report cards? It seems most likely that the Santa Monica Bay Epidemiological Study's influence is a function of its timing and location. The findings were reported by the Santa Monica Bay Restoration Project at the time AB 411 was being considered by the California legislature and were published in the journal *Epidemiology* at the time that the California Department of Health Services was promulgating the regulations to implement AB 411. Although several previous studies also concluded in favor of an association between water-quality indicators and health risks from ocean water recreation, the Santa Monica Bay Epidemiological Study was the most recent contribution to the literature at the time when the new coastal water-quality monitoring regime in California was being adopted. Second, and even more obviously, the Santa Monica Bay Epidemiological Study hit Californians where they live. Findings of studies from the Atlantic coast, Britain, Australia, South Africa, France, Israel, Egypt, and New Zealand understandably did not have the same impact on California regulators, reporters, and the public as a study conducted at their own front door.

Certain implications of the Santa Monica Bay Epidemiological Study remain to be pursued. One is the connection to urban runoff and all of the remedial measures currently being taken to control urban runoff in Southern California. The other is the economic consequences of those measures, compared with potential benefits of reducing the number of illnesses among recreational water users. These are the subjects of the next chapter.

# CHAPTER SIX
# RISKS, COSTS, AND BENEFITS

How much additional illness among beachgoers in Southern California might be attributed to coastal water quality, and what costs are associated with those illnesses? Another way of phrasing this question is to ask what are the benefits (in terms of reduced illnesses and associated costs) of improving water quality? And how do these figures compare with the expected costs of various coastal runoff reduction and treatment measures being undertaken by Southern California coastal communities?

This chapter attempts to address these vital questions, and does so in three steps. The first step is to develop estimates of the number of excess illnesses among recreational water users that might be attributable to coastal water-quality, based on the findings of the Santa Monica Bay Epidemiological Study. The second step is to estimate costs associated with those excess illnesses, which also provides a measure of the benefits that would be gained if the excess illnesses could be eliminated through water-quality improvements. The third step is to present for comparison the expected costs of some of the runoff reduction and treatment activities being undertaken along the coast.

## 1. A Model of Excess Illness Risks, Based on the Santa Monica Bay Epidemiological Study

Since they were first released in 1996, the findings of the Santa Monica Bay Epidemiological Study have been publicized extensively, if not always accurately. Most media reports focused on the study's supplemental cumulative measures of relative risk and excess cases. These supplemental measures were presented in an addendum to a public-information summary published by the Santa Monica Bay Restoration Project. For example, the *Los Angeles Times'* lead story on the study reported:

> An unprecedented health survey shows that Santa Monica Bay beach-goers who swim near storm drains are almost 50 percent more likely to contract colds, sore throats, diarrhea and other illnesses than those who swim farther away in cleaner water . . . In raw numbers, the survey projects that 373 of every 10,000 people (about 4 percent) swimming near drains will contract at least one symptom — cough, ear ailment, sore throat, fever, chills or some gastrointestinal disorder. "To put it another way, that means that if you bring a classroom of 25 kids out there to swim in that polluted water, one of them is going to get at least one of these symptoms. That's what this study shows," said Mark Gold, Executive Director of the environmental group Heal the Bay and a driving force behind the study (Rainey, 1996).

This article, however, inaccurately described the actual set of statistically significant symptoms used to calculate the cumulative risks and excess case estimates at the zero-yard point (i.e., directly in front of a storm drain). The article also stated that health risks increased by swimming "near storm-drains." The cumulative risk data presented in the Santa Monica Bay

Epidemiological Study addendum, however, solely reflected outcomes associated with swimming *directly in* the outfall flow.

Finally, the article confused excess cases with total expected cases. The Santa Monica Bay Epidemiological Study data showed, for example, that there would be 459 cases of SRD per 10,000 swimmers in control waters versus 762 per 10,000 at the drain. This means that one in 25 children could be expected to exhibit SRD *irrespective* of where they swam. If the group chose to swim at the drain, the data suggests that an additional 0.66 children would be expected to exhibit SRD symptoms.

One might well ask, who cares if reporters did not quite get the study findings right? One answer is that these discrepancies between the study's findings and the ways they were reported have significant consequences when the study's results are imputed to the entirety of Los Angeles County's 50-mile beachfront, and even more significant consequences if those extrapolations become the basis for policy responses by coastal communities.

For example, if health risks at every spot along the beachfront were treated the same as the Santa Monica Bay Epidemiological Study's maximum reported risks that occurred only at the drains, the projected number of excess illnesses per year would be quite high. A substantially different estimate of health risks would result, however, if the Santa Monica Bay Epidemiological Study results for storm-drain locations are applied only to comparable flowing drain points along county beaches, while areas away from those flowing drains are treated as comparable to Santa Monica Bay Epidemiological Study control locations.

To address these issues, we have created an excess risk model (ERM) of annual excess cases of illness for Los Angeles County beaches based on the results of the Santa Monica Bay Epidemiological Study. We will use the Santa Monica Bay Epidemiological Study's measurements of excess illness cases, rather than the RR ratios in Santa Monica Bay Restoration Project's public information document.[51] We will apply those excess illness rates to the remainder of the Southern California coastline using the following variables and conventions:

***Number of Swimmers per Year***

Estimates of beach visitors per year in Los Angeles County range from about 40-million to 50-million people (Rainey, 1996; Haile et al., 1996). The ERM will use the higher limit of this estimate, or 50-million people per year.

***Repeat Versus Single Exposure Risks***

The Santa Monica Bay Epidemiological Study was designed to identify risks associated with single rather than multiple exposures. Many beachgoers are repeat visitors. Repeated exposures could change the single exposure risks identified in the Santa Monica Bay Epidemiological Study in several ways, although which direction the results would change is not known. It may be that repeat swimmers are weakened by additional contamination and become sick more often, or it may be that they might develop some resistance from repeated exposure to the pathogens.[52] Because repeated exposure effects are unknown, the ERM assumes that

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51 There are two reasons for using the number of excess cases rather than the RR ratios. First, the number of excess cases is useful for calculating the associated costs per illness, while the RR ratios are not. Second, while RR ratios are often used to report cohort study results, they can distort true health concerns. Consider two examples: 1) If four people of 10,000 were to contract SRD in a control group compared with 10 of 10,000 at a storm drain, the RR ratio at the drain would be 2.50, a very high ratio (which would exceed any reported in the Santa Monica Bay Epidemiological Study). The actual number of excess cases per 10,000, however, would be six, a relatively small number when considered from the standpoint of mounting a major public health response. 2) On the other hand, if 4,800 people of 10,000 fell ill at the drain compared with 4,600 in control waters, the RR ratio would be 1.04, suggesting almost no elevated risk. Yet 200 additional illness cases per 10,000 swimmers would have occurred, a relatively high number with significant public-health consequences.

52 Potential immunity effects are discussed in Haile et al. (1996, 1999).

each incidence of swimming generates an independent risk of illness unaffected by prior or subsequent exposures. This approach may understate or overstate the true excess cases induced in the population of beachgoers.

***Swimmer Distribution Relative to Outfall-Impacted Areas***

The Santa Monica Bay Epidemiological Study focused on approximately 800-yard study areas associated with three perennially flowing storm drains or outfalls. Swimmers in waters at least 400 yards either side of the drain were considered to be unexposed to whatever contaminants it carried. The study assumed that all potentially elevated risks were confined to approximately 100 yards either side of the perennial drain flow, and most significant risks were identified only at the drain.

By various measures, there are from 12 to 19 perennial or near-perennial drain outfalls affecting Los Angeles County beaches.[53] The balance of the county's beach outfalls do not flow except in wet weather or intermittently as a result of irrigation runoff or brief dry-period storm events.

In dry periods, then, about 1.4 to 2.2 miles (2.7 percent to 4.3 percent) of Los Angeles County's 50-mile beachfront could fit the Santa Monica Bay Epidemiological Study health-risk profile.[54] The other 95 percent or more of the coastline is beyond 100 yards of a flowing drain and, at least in dry periods, should experience water quality similar to the study's "control" waters. This interpretation of the Santa Monica Bay Epidemiological Study data corresponds with the Santa Monica Bay Restoration Project's own public assessment that health risks are confined to within 100 yards of a flowing drain and attenuate rapidly beyond that:

> Swimmers outside the drainage areas were far less likely to fall ill, perhaps little more than if they had swum in a pool or stayed out of the water altogether. "The good news is that, of the bay's 50-plus-mile coastline, less than two miles are problematic," [Santa Monica Bay Restoration Project's] summary of the [Santa Monica Bay Epidemiological Study] said (Rainey, 1996).

If swimmers were distributed randomly or evenly along Los Angeles County beaches, on average approximately 95 percent would be expected to swim in areas that do not fit the Santa Monica Bay Epidemiological Study outfall area risk profile. Of course, swimmers are not distributed randomly or evenly. Certain perennial-flow impacted beaches, such as Malibu, are particularly popular due to their recreational or locational amenities. Drainages at other locations may also flow for short periods of time and expose nearby swimmers to the illness risks identified by the Santa Monica Bay Epidemiological Study.[55]

To account for the potential clustering of beachgoers in areas affected by either perennial or intermittent drain discharges (including the presumably small number of wet weather beachgoers), the ERM assumes that 50 percent of all annual beach visitors swim in the 5 percent or less of the coastline that fits Santa Monica Bay Epidemiological Study risk profiles. Conversely, it is assumed that 50 percent of all beachgoers frequent the 95 percent of beaches

53 The most commonly identified year-round flowing outfalls are: Malibu Creek and Lagoon; Topanga Creek at Topanga Canyon Boulevard; Santa Monica Canyon, at Chautauqua Boulevard and West Channel Road; Montana Avenue, Santa Monica; Santa Monica Pier; Ashland Avenue, Santa Monica; Windward Avenue, Venice; Ballona Creek, Marina del Rey; 28th Street, Hermosa Beach; 16th Street, Hermosa Beach; Herondo Street, Redondo Beach; Avenue I, Redondo Beach, and Pico Boulevard (partially diverted to a sewer system) (Rainey, 1996; Rainey and Willogren, 1996).

54 Based on an exposure area of 200 yards times 12 to 19 perennial drains along a 50-mile coastline.

55 It is possible that contaminants from an intermittent drain would be more concentrated than from a perennial drain, although substantial delays between discharges may also tend to reduce the population or pathogenicity of disease-causing bacteria or viruses. Although we found these issues raised occasionally, we did not find data reported anywhere that would shed light on how these phenomena actually occur, if at all.

not affected by perennial drain flows at times when intermittent flows do not adversely harm water quality.

***Swimmer Distribution Within Outfall Impacted Areas***

As seen in Chapter 5, the Santa Monica Bay Epidemiological Study risk profile is heavily focused at the drain location (see Figures 5.1 and 5.2). According to the Santa Monica Bay Epidemiological Study's methodological summary, on-site researchers approached and attempted to interview all potentially eligible swimmers in each study area at the three subject beaches. The data show that of the more than 11,000 people interviewed and subsequently qualified by the study, 26 percent swam in the control areas, 28 percent in the 51-to-100-yard range from the drain, 39 percent in the 1-to-50 yard range, and 7 percent at the drain. These numbers exclude swimmers in waters located 101 to 399 yards to either side of the drain and those non-qualified, including repeat bathers.[56]

The Santa Monica Bay Epidemiological Study findings also exhibited beach-specific differences in the apparent willingness of swimmers to bathe at a drain. For instance, over 15 percent of the total respondents at Malibu were found to be swimming directly in the drain flow, perhaps because the drain fronts a well-known surfing beach. In contrast, approximately 3 percent of the study respondents at Ashland and 5 percent at Will Rogers swam at the drain (Table 6.1). For this reason, although Malibu swimmers represented only 34 percent of the total Santa Monica Bay Epidemiological Study dataset, they accounted for 70 percent of the study's cases of swimmers directly at storm drains.

*Table 6.1* Distribution of Swimmers Along Santa Monica Bay Epidemiological Study Beaches

| Beach | Control Area (%) | 51 to 100 Yard Range (%) | 1 to 50 Yard Range (%) | Drain (%) |
|---|---|---|---|---|
| Santa Monica Bay Epidemiological Study Aggregate | 26 | 28 | 39 | 7 |
| Malibu | 25 | 25 | 35 | 15 |
| Ashland | 26 | 28 | 43 | 3 |
| Will Rogers | 27 | 35 | 33 | 5 |
| Ashland and Will Rogers | 26 | 30 | 41 | 3 |

*Source: Calculated from the Santa Monica Bay Epidemiological Study (Tables 31 to 33).*

These data suggest that when a beach does not offer an attractive amenity at the drain site, people will tend to avoid swimming directly in outfall effluent. Attitudinal studies of swimmer perceptions of beach risks are consistent with this assessment.[57] Few, if any, of the other commonly cited perennial outfalls in Los Angeles County drain areas contiguous to beaches as popular, accessible, and recreationally unique as Malibu.

To account for these factors, the ERM adopts the aggregate swimmer distribution for outfall-impacted sites reported from the Santa Monica Bay Epidemiological Study data. This approach appears conservative (i.e., it probably overstates the number of swimmers at the drain) since:

56 The Santa Monica Bay Epidemiological Study states that researchers contacted "every potentially eligible beach visitor in their assigned zones" (Haile et al., 1996). Certain individuals from the final data, however, including those who entered the water again after the initial interview, were not included in the reported results.

57 See Pendleton (2001): "[W]hile people tend to avoid beaches with active storm-drains, they are drawn to beaches that offer 'easily managed amenities,' including parking, rental concessions, and restaurants." Quoted with permission of author.

- The reported percentage of swimmers at the drain in the aggregate Santa Monica Bay Epidemiological Study data (7 percent) incorporates the Malibu case, which is unusual.
- The exclusion from Santa Monica Bay Epidemiological Study statistics of all swimmers at 101-to-399-yard distances from drains over-assigns the percentage of other swimmers to the drain and other locations.

***Drain Area Risk Profiles***

The Santa Monica Bay Epidemiological Study aggregate risk profile displayed in Chapter 5 (see Figures 5.1 and 5.2) assumes that the incidence of disease is more or less uniform in each drain-impacted area. The individual beach data for each study site, however, suggests substantial variance in the risks associated with perennial storm drains.

Figure 6.1 shows that, for SRD, HCGI1, and HCGI2, the Malibu risk data profile is substantially higher than the Ashland/Will Rogers data profile. All three symptom groups and SRD in the 51-to-100-yard range exceeded 100 cases per 10,000 swimmers in the Malibu results. The only data point in the Ashland/Will Rogers profile with more than 32 excess cases of any reported illness — one-third the level the Santa Monica Bay Epidemiological Study identified as "noteworthy" — is SRD directly at the drain. HCGI1 and HCGI2 excess cases reported for Ashland and Will Rogers were below the control level even at the drain.

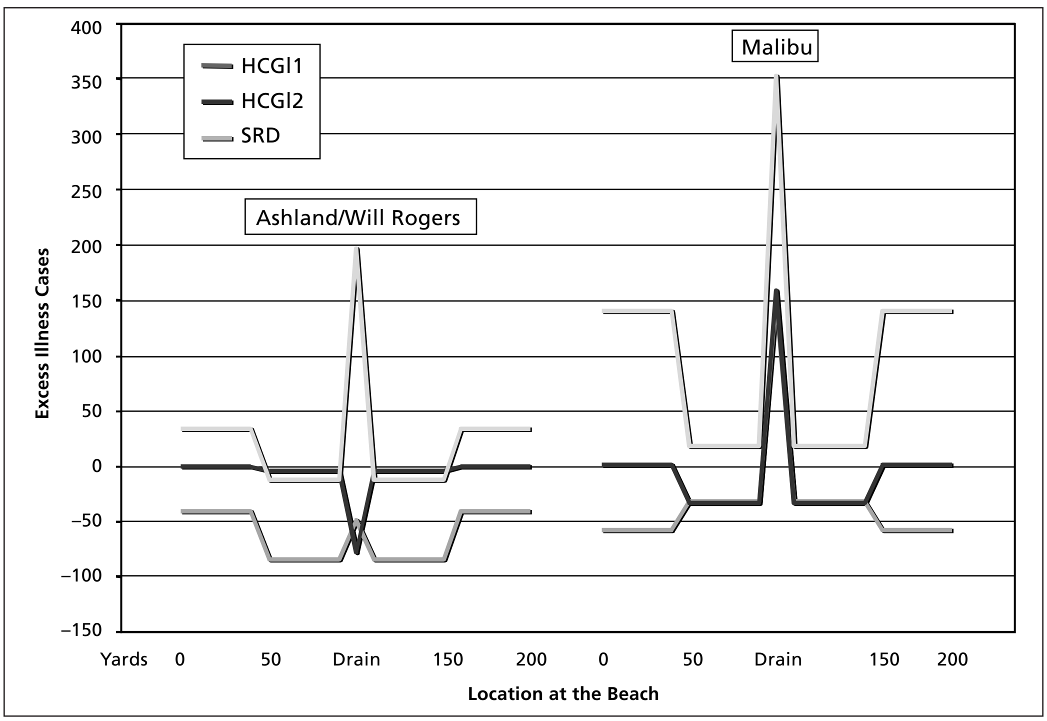


*Figure 6.1.* Average Excess cases of SRD, HCGI1, and HCGI2 at the Drain, and 0 to 50 Yards and 51 to 100 Yards Malibu and Ashland/Will Rogers study locations. Source: Calculated from the Santa Monica Bay Epidemiological Study (Tables 31 to 33).

One reason for this divergence may be that the Malibu beachfront lies at the foot of an extremely distinct watershed while Ashland and Will Rogers are affected by more typical, urbanized storm-drain systems. Malibu's drainage is fed by stream flows that may concentrate disease-causing agents because they accumulate untreated septic tank seepage, horse and animal waste, and effluent from upstream sewage treatment facilities (Los Angeles County Grand Jury, 2000). And previously noted, swimmers at Malibu appear to be attracted to areas of greater health risk for recreational reasons.

To account for location-specific storm-drain risk profile variance, the ERM will assume that 50 percent of the outfall-impacted beaches have the Malibu beach risk profile and 50 percent reflect the Ashland/Will Rogers data. This, too, is a conservative assumption. Most perennial outfalls in Los Angeles County drain urbanized areas similar to Ashland and Will Rogers, and none quite matches the risk-enhancing features of Malibu. The assumption that half of all outfall locations have the same risk profile as Malibu may, thus, overstate the likely distribution of risk.

***Excess Case Measurement***

As the Santa Monica Bay Epidemiological Study research team observed in 1996, assessments of the net illness risks associated with dose-response exposures cannot be easily made from data reported for each symptom or symptom group. Summing the total excess cases for several symptom reports will significantly overstate the true health risks because many co-occur. As Table 6.2 demonstrates, when the Santa Monica Bay Epidemiological Study researchers controlled for co-occurrence of statistically significant symptoms at the drain, the extent of this overstatement ranged from 48 to 79 percent.

*Table 6.2* Santa Monica Bay Epidemiological Study Unadjusted and Adjusted Cumulative Excess Cases per 10,000 Swimmers at the Drain for Statistically Significant Symptom Reports

| Symptoms | Raw Cumulative Result | Adjusted for Multiple Response | Ratio of Affected Individuals to Number of Excess Cases |
|---|---|---|---|
| Fever, Chills, Ear Discharge, Vomiting, Phlegm | 772 | 373 | 0.48 |
| SRD and HCGI2 | 399 | 314 | 0.79 |

*Sources: The Santa Monica Bay Epidemiological Study (Tables 17 to 24) and the Santa Monica Bay Epidemiological Study Public Information Release Addendum.*

The Santa Monica Bay Epidemiological Study apparently did not calculate adjusted cumulative risk measurements for comparable symptoms at other non-control study locations. As a result, it is not possible to assess with the same precision as the drain data the extent to which excess cases of the five relevant individual symptoms, SRD, or HCGI2 were identified at non-drain locations.

The ERM reports results for five different symptom groups:

(i) Total excess cases of HCGI1.

(ii) Total excess cases of HCGI2.

(iii) Total excess cases of SRD.

(iv) Total excess cases of at least one report of fever, chills, ear discharge, vomiting, or coughing with phlegm, using the actual drain risk profile calculated by the Santa Monica Bay Epidemiological Study researchers, and adjusting the raw reported data for other locations by the same ratio as the drain data.

(v) Total excess cases of either SRD or HCGI2, using the actual drain risk profile calculated by the Santa Monica Bay Epidemiological Study researchers, and adjusting the raw reported data for other locations by the same ratios as the drain data.

Measures (i) to (iii) represent excess cases of highly credible symptom groups that correlate with total excess risks, although they may overstate or understate them when considered independently from each other. Measures (iv) to (v) provide a more comprehensive measure of total excess cases based on the statistically significant results obtained at the drain, although the use of the drain scaling factors for other locations may over or understate the true excess case outcomes.

***Significance Weighting***

The Santa Monica Bay Epidemiological Study found almost no statistically significant dose-response results at any study location but the drain. Data from non-drain locations suggested certain elevated or reduced levels of risk, but not outside the range of random chance. That is why the Santa Monica Bay Epidemiological Study researchers limited their own cumulative risk assessments to the statistically significant drain dataset, as noted in Chapter 5.

If data from the non-drain locations are included in the ERM, they will generate relatively large negative or positive changes in total excess case estimates (Table 6.3). The 1-to-50-yard ranges, for example, show below control (negative) numbers of excess HCGI1, HCGI2, and SRD cases. In an aggregate model, those results would lower the net excess case calculations. In contrast, SRD incidences in the 51-to-100-yard range equal about 76 excess cases, a result that increases total reported risks in the ERM.

*Table 6.3* Excess HCGI1, HCGI2, and SRD Cases per 10,000 Swimmers at All Santa Monica Bay Epidemiological Study Locations Combined

| Symptom Cluster | Controls 400 Yards from Drain | 51 to 100 Yards from Drain | 1 to 50 Yards from Drain | Drain |
|---|---|---|---|---|
| HCGI1 | 0 | –47 | –69 | 87 |
| HCGI2 | 0 | –1 | –15 | 96 |
| SRD+ | 0 | 76 | –6 | 303 |

*Source: Calculated from Haile et al. (1999). The reported cases in the 1999 article differ slightly from the Santa Monica Bay Epidemiological Study reports, apparently due to various adjustments reflecting age, sex, and similar respondent demographics. Also, the drain distances are upcoast and downcoast combined; therefore, these figures do not correspond precisely with those in the tables in Chapter 5.*

Including the non-drain dose-response data provides a more comprehensive way of assessing beach health risks, but introduces data the Santa Monica Bay Epidemiological Study did not find statistically significant into the model. To address these significance and comprehensiveness concerns, the ERM adopts two reporting protocols:

- Total excess risks are reported for calculations based on unadjusted results ("Protocol [i]").
- Total excess risks are reported by eliminating non-statistically significant data points identified in the Santa Monica Bay Epidemiological Study ("Protocol [ii]").

Protocol (i) treats the various symptom reports generated by the Santa Monica Bay Epidemiological Study as equally valid. Protocol (ii) is in accord with the Santa Monica Bay Epidemiological Study researchers' own assessments that no dose-response relationship could be discerned in the study results other than at the drain.

Table 6.4 presents the excess case estimates yielded by the ERM, using the variables and conventions described above, and reported in terms of number of affected individuals. It suggests that the adverse water-quality risks identified by the Santa Monica Bay Epidemiological Study could be expected to generate excess cases raging from -83,997 (fewer than control) individuals with HCGI1 per 50-million beachgoers under Protocol (i) conventions to approximately 110,301 individuals with SRD per 50-million beachgoers under Protocol (i) conventions.[58]

58 To provide a measure of ERM sensitivity, the ratio of swimmers exposed to Santa Monica Bay Epidemiological Study risks was assessed between extremes of 5 and 95 percent. If the percentage of people exposed to Santa Monica Bay Epidemiological Study risk profiles is assumed to be as high as 95 percent of all beachgoers, the range of excess cases varies from approximately -159,000 (HCGI1, protocol (i)) to approximately 229,000 (SRD, protocol [i]), about double the base case estimates. If the percentage of people exposed to Santa Monica Bay Epidemiological Study risk profiles is assumed to be as low as 5 percent of all beachgoers, the range of excess cases varies from approximately -8.400 (HCGI1, protocol [i]) to approximately 11,000 (SRD, protocol [i]), about 90 percent less than the base case estimates.

*Table 6.4* Estimated[a,b] Excess Number of Individuals in Los Angeles County per Year Affected by HCGI1, HCGI2, SRD, the Five Significant Symptom Cluster, and SRD or HCGI2

| Symptom Cluster | Control and Other Non-Drain Impacted Areas | Excess Illnesses, 51 to 100 Yard Range from Drain | Excess Illnesses, 1 to 50 Yard Range from Drain | Excess Illnesses at Drains | Total Excess Individuals Affected[(g)] (Protocol i) | Total Excess Individuals Affected[(h)] (Protocol ii) |
|---|---|---|---|---|---|---|
| Percent of Swimmers | 63 percent[(f)] | 14 percent | 19.5 percent | 3.5 percent | | |
| HCGI1[(c)] | NA | –35,745 | –57,170 | 8,918 | –83,997 | n/a |
| HCGI2[(c)] | NA | –331 | –19,316 | 6,855 | –12,791 | 6,855 |
| SRD[(c)] | NA | 60,473 | 1,549 | 48,278 | 110,301 | 48,278 |
| Five Symptom Cluster[(d, e)] | NA | 8,883 | –24,288 | 56,147 | 40,741 | 56,147 |
| SRD or HCGI2[(e)] | NA | 47,513 | –14,036 | 43,555 | 77,033 | 43,555 |

*Notes:*

*(a) Assumptions:*
*Total Annual Swimmers . . . . . . . . . . . . . . . . . . . . . . . . 50,000,000*
*Percent of Swimmers in Non-Drain Areas . . . . . . . . . . . . . . 50 percent*
*Percent of Drain Areas like Malibu . . . . . . . . . . . . . . . . . . 50 percent*
*Scaling Factor: Five Symptom Cluster. . . . . . . . . . . . . . . . . 0.48*
*Scaling Factor: SRD or HCGI2 . . . . . . . . . . . . . . . . . . . . . 0.79*

*(b) The drain risk profile assumption (i.e., that 50 percent of all drain-impacted areas in Los Angeles County have the health risk profile displayed by Malibu in the Santa Monica Bay Epidemiological Study) means that the figures in this table were not calculated directly from the figures in Tables 6.1, 6.2, and 6.3.*

*(c) HCGI1, HCG2, and SRD results are unadjusted.*

*(d) "Five Significant Symptom Cluster" means one or more reported cases of the five symptoms with significant results reported at the drain in the Santa Monica Bay Epidemiological Study: fever, chills, ear discharge, vomiting, or coughing with phlegm.*

*(e) Five significant symptom and SRD or HCGI2 results scaled for non-drain areas by factors identified for the drain data (see Table 6.3).*

*(f) Allocation of swimmers to control area reflects assumption that 50 percent swim outside Santa Monica Bay Epidemiological Study areas, and that 26 percent of the 50 percent swimming in study areas swim in the control portions of those areas (per Table 6.3)*

*(g) Protocol (i) reports results for all locations irrespective of dose-response significance identified in the Santa Monica Bay Epidemiological Study.*

*(h) Protocol (ii) reports only significant dose-response results identified in the Santa Monica Bay Epidemiological Study.*

*NA = Not applicable.*

## 2. Quantifying Beach Water-Quality Health Risk Costs

### *Excess Illness Direct and Indirect Costs*

Illness attributed to marine stormwater contamination ranges from mild discomfort to relatively severe colds or flu. As one environmental advocate has observed, marine water illnesses "rarely threaten human life; however, they can lead to significant physical discomfort, cause a person to miss work, and be spread to other persons."[59] The most chronic and credible illnesses identified in the Santa Monica Bay Epidemiological Study, including SRD and the two HGCI symptom co-occurrences, appear to most closely resemble influenza.

The direct and indirect costs attributed to non-fatal, influenza-like diseases commonly include estimates of:

- Lost or reduced work productivity.
- Outpatient doctor visits and medicine costs.
- The likelihood of and expenses associated with an illness requiring hospitalization.
- The likelihood of and loss of lifetime earnings associated with an illness that causes death.

59 Testimony of David Younkman, Executive Director, American Oceans Campaign before the House Transportation Water Resources And Environment Subcommittee, Shore And Beach Legislation, August 6, 1998.

There have been numerous studies of such per-illness influenza expenses. A recent and comprehensive data review was published in March 2001 (Nichol, 2001) and provides estimates of direct and indirect costs per flu incident (Table 6.5).

Under this analysis, each case of influenza affecting an employed person costs approximately $387. About 63 percent of all surveyed beachgoers in the Santa Monica Bay Epidemiological Study were younger than 19 years of age; however, only 26 percent were older than 25 years of age (Haile et al., 1996). Although parents or guardians of younger swimmers who become ill will likely experience medical and productivity-related costs to care for their children, it seems reasonable to assume that, among these younger and less-employed individuals, some of the illness costs that are based on lost income will be lower.

*Table 6.5* Direct and Indirect Costs of Influenza-Related Illness

| Type of Cost | Measure | Notes |
|---|---|---|
| Average Work Days Lost per Illness | 2 | |
| Average Days Productivity Loss Due to Reduced Work Efficiency | 0.35 | 0.7 Days of 50-percent Work Efficiency |
| Average Total Productivity Loss Per Illness | $338.40 | $18.00 per Hour Regional Median Wage for Full-Time Workers Times 18.8 Average Lost Hours of Work |
| Average Doctor Visit Costs Per Illness | $45.90 | $102.00 per Visit Times 0.45 Visits per Illness (Includes Medicines and Co-Payments) |
| Average Hospitalization Costs Per Illness | $2.27 | Four Hospitalizations per 10,000 Illnesses Times $5,669.00 per Hospitalization |
| Average Death Coasts Per Illness | $0.76 | One Death per 1 Million Illnesses Times Average $760,000 Net Present Value of Lost Lifetime |
| Total Costs per Illness | $387.33 | |

*Source: Nichol (2001). The hourly wage rate reported in the original study was $15 per hour based on United States data. Recent compensation surveys of the Southern California area, however, indicate that the regional average hourly wage rate is approximately $18 per hour. The reported data was adjusted to reflect the County's average wage. United States Bureau of Labor Statistics, National Compensation Survey, Los Angeles-Riverside-Orange Counties, April 2000.*

To account for this factor, the ERM estimates that 85.2 percent of all beach-related illnesses generate full-time worker influenza expenses (i.e., it assumes that the 25-and-older cohort [26 percent of the total] is fully employed, and that 80 percent of the remaining beachgoing cohort younger than 25 years [74 percent of the total] generates full-time illness costs). Under these assumptions, the annual cost associated with net excess beach illnesses in Los Angeles County (see Table 6.5) ranges from about $36.4 million (SRD, protocol [i]) to -$27.7 million (HCGI1, protocol [i]) (Table 6.6).[60]

In addition to illness-related costs, many analysts and media reports suggest that perceptions of adverse water quality can reduce recreational income for the affected beach areas.[61] One study estimates that the annual direct recreational spending for food, gas, parking, and other beach-related amenities in California is about $14 billion per year. Using an economic multiplier

60 If the percentage of people exposed to Santa Monica Bay Epidemiological Study risk profiles is assumed to be as high as 95 percent of all beachgoers, the cost range is from -$53 million (HCGI1, protocol [i]) to approximately $69 million (SRD, protocol [i]). If the percentage of people exposed to Santa Monica Bay Epidemiological Study risk profiles is assumed to be as low as 5 percent of all beachgoers, the cost range is from -$2.7 million (HCGI1, protocol [i]) to approximately $3.6 million (SRD, protocol [i]).

61 As one article stated, "Millions of Californians live near the water, and beach-oriented recreation drives a $64-billion a year tourism industry." "A Scary Portrait of Coastal Waters." Editorial, *Ventura County Star* (July 18, 1999). This estimate inaccurately uses the national indirect and direct fiscal impact figures as the local tourist economy figures.

*Table 6.6* Direct and Indirect Annual Excess Illness Costs

| Illness | Direct and Indirect Costs: Protocol (i) | Direct and Indirect Costs: Protocol (ii) |
|---|---|---|
| HCGI1 | –$27,719,443 | Not Available |
| HCGI2 | –$4,221,096 | $2,262,185 |
| SRD | $36,399,899 | $15,931,989 |
| Five-Symptom Cluster | $13,444,740 | $18,528,799 |
| SRD or HCGI2 | $25,421,287 | $14,373,374 |

*Excess cases shown in Table 6.4, with 85.2 percent of cases generating an economic loss of $387.33. Protocols are as defined in Table 6.4, notes (g) and (h).*

methodology, the total annual indirect economic benefit to the entire United States attributable to California's beaches has been estimated at $73 billion (King, 1999).

Los Angeles County encompasses approximately 5.9 percent of the state's beach coastline and about 8.9 percent of California's reported total annual per person visits. Assuming all visits produced roughly comparable economic effects, the County's share of statewide direct beach spending would range from about $826.0 million (based on coastline) to about $1.25 billion (based on annual visits) and contribute from $4.3 to $6.5 billion to the national economy.[62]

It has been suggested that a reported 32-percent decline in Los Angeles County beach use from 1983 to 1997 may have been attributable to adverse news reports about water-quality (Los Angeles County Grand Jury, 2000). Survey data have shown that the public is influenced in beachgoing decisions by perceived water-quality risks (Martin and Pendleton, 2000). Assuming that the entire reported decline in County beach usage in 1983 to 1997 was due to water-quality — an average 2.1 percent decline per year — the total direct annual recreational income losses to Los Angeles County might plausibly range from $17 million to $26 million.

There are, however, no comprehensive assessments of how perceptions of beach water quality affect recreational income.[63] Any such estimate cannot currently assess such crucial factors as:

- Whether beach use estimates are accurate over time (many are based on different methods in different years).
- The extent to which reported declines might be occurring for reasons other than water quality.
- The extent to which recreational dollars not spent on beaches are instead allocated in other ways that might be at least as valuable to the local and national economies.

At present, we believe that the most defensible beach health risk cost assessments are those derived from the Protocol (ii) excess case estimates. Protocol (ii) data rely exclusively on the statistically significant symptom data reported in the Santa Monica Bay Epidemiological Study. Since such symptoms are clustered directly at the drain, Protocol (ii) cost estimates are primarily affected by the allocation of swimmers to drain areas. Since Protocol (ii) excludes statistically insignificant non-drain findings, many of which generate negative excess case estimates, it generates higher cost estimates for each symptom cluster except SRD.

62 Beach-accessible coastline: 50 miles for Los Angeles County versus 840 miles for all of California. Beach visits per year: 50 million for Los Angeles County versus 559 million for all of California. King (1999). See Tables 1.4 and 2.1.

63 The California Water Resources Control Board, the University of Southern California, the University of California, Berkeley, and the University of California, Davis, have collaborated on a study titled, "Southern California Beach Valuation Project," which includes an effort to characterize the connection between water-quality issues and beach economic effects. The study's web site is http://marineeconomics.noaa.gov/scbeach/welcome.html.

Table 6.7 summarizes a range of potential annual costs associated with the base ERM case (50 percent of all swimmers in drain-impacted areas) and two outlier cases (5 and 95 percent of all swimmers assumed to be in drain-impacted areas). The results show that the highest annual cost estimate based on Protocol (ii) conventions is associated with expected excess cases of the five significant symptom cluster. The table also indicates that if comparatively few people swim directly in running storm drains at county beaches, the estimated costs attributable to excess cases of all symptoms would average about $1.3 million per year. If 95 percent of all swimmers bathe at the drains of drain-impacted beaches, the estimated average annual cost rises to about $24 million per year. The base ERM estimate indicates an average annual cost of about $12.8 million per year.

*Table 6.7* Estimated Annual Costs of Excess Illnesses, Protocol (ii) Estimate Range

| Illness | Estimated Costs of Excess Illnesses Assuming 50 percent of Swimmers in Drain-Affected Areas (from Table 6.6) | Range of Estimated Costs of Excess Illnesses, Assuming 5 to 95 Percent of Swimmers in Drain-Affected Areas |
|---|---|---|
| HCGI1 | Not Available | Not Available |
| HCGI2 | $ 2,262,185 | $225,692 to $4,288,149 |
| SRD | $15,931,989 | $1,589,460 to $30,199,740 |
| Five Symptom Cluster | $18,528,799 | $1,848,523 to $35,121,935 |
| SRD or HCGI2 | $14,373,374 | $1,433,970 to $27,245,432 |
| Average (of the Four Rows Above) | $12,774,086 | $1,274,411 to $24,213,814 |

### 3. Beach Water-Quality Remediation Costs and Benefits

Cost-benefit analysis assumes a specific policy is worth pursuing if the expense of that policy is less than the costs associated with taking no action. Depending on the number of people exposed to drain effluent in the course of a year, Table 6.7 suggests that public polices ranging from a few hundred-thousand dollars to as much as $35 million per year (the high end of the range of cost estimates for the five significant symptom cluster) may be justified. The base model suggests that annual policy responses of $12.8 million would generate at least comparable benefits if they eliminated excess beach-related illnesses.

Many water-quality policy responses, however, involve potentially large expenditures for fixed capital construction, such as treatment plants, sewer diversions, or catchment basin filtration retrofitting. The costs associated with these measures are typically incurred over short periods and then “pay off” over time. To estimate the potentially justifiable range of such capital investments, Table 6.8 calculates the net present value of the health costs attributable to beaches in Los Angeles County under Protocol (ii) conventions and using the highest reported costs (the five-symptom cluster) over 50 years. These results suggest that capital expenditures of from $37 to $697 million in present value (base case = $366 million) might be justified if they reduced illness rates to background or control levels.

*Table 6.8* Net Present Value of 50-Year Annual Excess Illness Costs (Five Symptom Cluster), Using Protocol (ii) Estimate Ranges of 5 Percent, 50 Percent, and 95 Percent Swimmer Drain Area Exposure (Discount Rate = 5 Percent)

| Swimmer Distribution | Net Present Value |
|---|---|
| 5-percent Drain Area Exposure | $36,689,316 |
| 50-percent Drain Area Exposure | $366,893,160 |
| 95-percent Drain Area Exposure | $697,097,005 |

There are three categories of expenses associated with public-policy responses to adverse water-quality concerns:

- ***Direct implementation costs***, including planning, technical studies, construction, management, oversight, ongoing maintenance, and personnel and material expenses.
- ***Secondary costs***, associated with raising the funds to make the required public-policy expenditures, such as higher taxes and construction expenses, precluded development, redirected consumption expenditures, and associated public perception and economic multiplier effects.
- ***Policy opportunity costs***, the possibility that a public-policy expenditure generates less per-dollar benefits than other public-policy options, thus misallocating public funds from more to less effective actions.[64]

Precise estimates of most, if not all of the costs of policies to reduce adverse beach water-quality are currently unavailable. The possible range of expenses that water-quality concerns could generate, however, can be examined by considering various informal statements offered to the media over the past few years (Table 6.9). As the table shows, reported public-policy expenses vary considerably. Some appear to be well within the range that seems justifiable, given potential annual and net present value health risk costs. Others may cost substantially more than the problems they are intended to resolve. More expensive policies, however, might still be justified on the basis of such additional considerations as: (i) other public-policy objectives and benefits (sewer cleanups or trash collection, for example, have benefits that extend beyond reducing beach health risks); or (ii) other, as yet unspecified, beach health risk costs, such as lost recreational revenue, that may cause health risk cost estimates to rise.

When public-policy opportunity costs are considered, however, the data seem to strongly support policies that reduce or eliminate swimmer contact with direct drain flows. Under any aggregate health risk model based on the Santa Monica Bay Epidemiological Study results, reducing storm-drain water contact to zero all but completely eliminates the expected excess cases of illness — and, thus, the costs associated with such disease — among the beach going public.

One assessment of storm-drain avoidance efforts (Pendleton, 1999) suggests that by reducing attractive amenities near drains, such as parking, rental concessions, or restaurants, the public's general aversion towards beaches with active storm drains could be reinforced and facilitated. This strategy would work well for less popular areas, but probably be infeasible for those with special recreational features.

64 Public-policy opportunity costs have been examined extensively in Tengs et al. (1995) and Tengs and Graham (1996). Each of these studies was based on the results of a Harvard assessment of the benefits and costs of different interventions. The studies estimated that if the $185 billion spent on the various interventions under study had been reallocated from least to most effective, another 60,000 lives and 636,000 life years would be saved. See also the comparative benefit assessment made by Cohen (1991), which suggests that poverty, smoking, and obesity (all correlated with class and economic status) reduce life expectancies by several years compared with losses of at most a few days attributable to environmental toxic exposures. Public-policy opportunity cost assessments have been subject to criticism, but few dispute that (1) interventions and expenditures have different costs and benefits, and (2) misallocation of resources and lost opportunity costs can result from less optimal policy choices. See the discussion in Sunstein (1996).

*Table 6.9* Various Public-Policy Cost Estimates Reported in Recent Articles about Beach Water Quality in Southern California

| Potential Payor | Cost | Policy | Source |
|---|---|---|---|
| Los Angeles County | $1 million | 4-Month Campaign Awareness Campaign | American City and County, June 1999 |
| Huntington Beach | $1.2 million | Bacteria Study | Hawkinson, 1999a |
| Huntington Beach | $1.2 million | 20-Year Cost of City Sewer Upgrades | Reyes, 1999d |
| Los Angeles County | $30 million | Install Filters in 60,000 Catch Basins (Excludes Cleaning Expenses) | Cone, 1999d |
| Cities of Santa Monica | $8 million | Santa Monica Pier Area Runoff Diverter/Treatment | Cone, 1999d |
| Los Angeles County | $160 billion | Build Runoff Diversions for All County Stormwater Runoff in Periods 20,000 Units at 8 million | Cone, 1999d |
| Southern California | $14 billion | Ridding Southern California Water of All Bacteria and Virus Pollution | "Water Pollution" September 6, 1999 |
| Los Angeles County | $1.75 billion | 12-Year Trash Control Costs | Mozingo, 2001 |
| San Diego City | $12 million | Annual Cost of Compliance with New Runoff Standards | Rodgers, 2001 |
| San Diego County | $3.5 billion | Cost of Compliance with New Runoff Standards | Conaughton, 2001 |
| Orange County | $350,000 | Divert Huntington Beach Runoff with Blocks | "Runoff Diversion Gets Underway," 2001 |

Reducing storm-drain bathing might be achieved by access limitations alone, but this strategy might not address perception issues related to ongoing discharges that can generate adverse media attention. It would also be controversial in areas with unique recreational features affected by outfall flows, such as at Malibu. Since these factors are associated with higher health risks and costs, it seems reasonable to combine any drain-avoidance measures with remedial water treatment or diversion measures focused on recreational high-profile "hot spots."

## 4. Conclusion

Despite substantial, growing media and public concern, there is no simple way to calculate overall beach water-quality health risks from even highly publicized, credible studies like the Santa Monica Bay Epidemiological Study. Not surprisingly, it is also difficult to communicate such aggregate risk implications to the public. Nevertheless, several conclusions may be drawn from the data developed above.

- Based on the Santa Monica Bay Epidemiological Study excess cases of illness from dry-weather recreational water contact, beyond the number normally expected from a swimmer cohort, are associated almost exclusively with swimming *directly in* a flowing outfall's effluent. There is little support in the Santa Monica Bay Epidemiological Study data for the often-repeated contention that those who swim "near" a storm drain are significantly more likely to experience illness symptoms than those who swim farther away.

- Excess cases reported by the Santa Monica Bay Epidemiological Study for locations up to 100 yards on either side of a storm drain are generally not statistically significant, and when included in an overall risk model, actually tend to generate *fewer* overall excess illness estimates because many illness symptoms among water users within those distances were less common than among those in the control groups.
- Assuming that 50 percent of the swimming public chooses to bathe in areas within 400 yards of a flowing storm drain, and that 7 percent of those in drain-impacted areas swim *directly in* the flowing effluent, total annual excess cases in Los Angeles County of Santa Monica Bay Epidemiological Study five symptom, HCGI2 or SRD, and three highly credible symptom clusters range from negative to 110,000 for SRD. Using only the statistically significant Santa Monica Bay Epidemiological Study data generates an annual excess case estimate per 50-million people of from 6,800 to 56,000.
- Excluding perception impacts on recreational expenditures, the direct and indirect annual excess case costs in Los Angeles County of Santa Monica Bay Epidemiological Study five symptom, HCGI2 or SRD, and three highly credible symptom clusters ranges from -$27 million to $36 million. Using only the statistically significant Santa Monica Bay Epidemiological Study data generates an annual excess case cost estimate of from $2.3 million to $18.5 million.
- Absent covariant costs attributable to other causes or additional recreational and similar costs, public-policy options from $0 to $30 million per year (or one-time capital expenditures of from $37 million to $695 million) appear reasonably justified in light of the aggregate social loss estimates. When opportunity costs are considered, however, polices that minimize drain flow contact rather than major infrastructural responses appear to be the most cost effective and rational, particularly if combined with certain high profile “hot spot” remediation measures.

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