LITERATURE REVIEW AND ANALYSIS:

Coastal Urbanization and Microbial Contamination of Shellfish Growing Areas

Stuart Glasoe and Aimee Christy
Puget Sound Action Team, State of Washington
Olympia, Washington

June 2004

PUGET SOUND
ACTION TEAM
Office of the Governor

PO Box 40900
Olympia, WA 98504

Publication #: PSAT04-09

If you would like copies of this document in an alternative format, please call (800) 54-SOUND or for TDD, call (800) 833-6388.

LITERATURE REVIEW AND ANALYSIS:

Coastal Urbanization and Microbial Contamination of Shellfish Growing Areas

Stuart Glasoe and Aimee Christy
Puget Sound Action Team, State of Washington
Olympia, Washington

CONTENTS

INTRODUCTION

Many factors influence the suitability of coastal areas for growing and harvesting shellfish, and none is more vital than clean water. Human habitation has had a dramatic effect on the condition of the nation's coastal habitats and resources. A primary concern in shellfish growing areas—which are generally located in the intertidal and shallow subtidal coastal zone—is contamination from human sewage and animal wastes and the related health risks associated with the consumption of contaminated shellfish. Main sources of fecal pollution include municipal sewage systems, on-site sewage systems, stormwater runoff, marinas and boaters, recreationalists, farm animals, pets and wildlife.

As is the case with other coastal habitats, the condition and classification of shellfish growing areas generally correlate with human population densities and land uses in the adjacent shorelines and uplands. Rural watersheds with limited development and intact land cover are best suited for shellfish harvesting, and more developed watersheds are less so. Population growth and development are rapidly changing the landscape of coastal America and, in turn, are placing greater pressure on shellfish harvesting and other valued uses and functions of the coastal environment. When left unchecked, the process of urbanization—defined as the transformation of natural landscapes to built environments—can leave coastal areas permanently unfit for the harvest and consumption of shellfish. In Puget Sound, Washington, for example, more than a century of population growth and development along the Sound's eastern shore, from Everett to Tacoma, has essentially eliminated the opportunity to harvest shellfish in this area because of the health risks associated with the urban land uses and poor water quality. Similar impacts and correlations are also evident in other heavily populated areas the region where shellfish harvesting is not permitted (Figures 1 and 2).

Clearly there are different water quality conditions associated with different types, patterns, and densities of coastal development, but our limited understanding of these relationships hampers efforts to effectively manage land uses and control pollution to permanently safeguard water quality for shellfish harvesting in Puget Sound and other parts of the country. To better understand these important issues, the Puget Sound Action Team initiated a project to evaluate the relationship between coastal urbanization and microbial contamination of shellfish growing areas. This literature review is part of that project and is intended to provide an overview of the current state of knowledge on the subject. The findings have been combined with research conducted by the University of Washington and other available information to produce new guidelines for protecting shellfish growing areas in Puget Sound. The U.S. Environmental Protection Agency provided funding for the project.

TRENDS IN COASTAL GROWTH

Coastal areas are uniquely productive, valuable, and fragile environments. They are also uniquely attractive and desirable places to live, work, and play. This leads to the complex and challenging task of accommodating growth

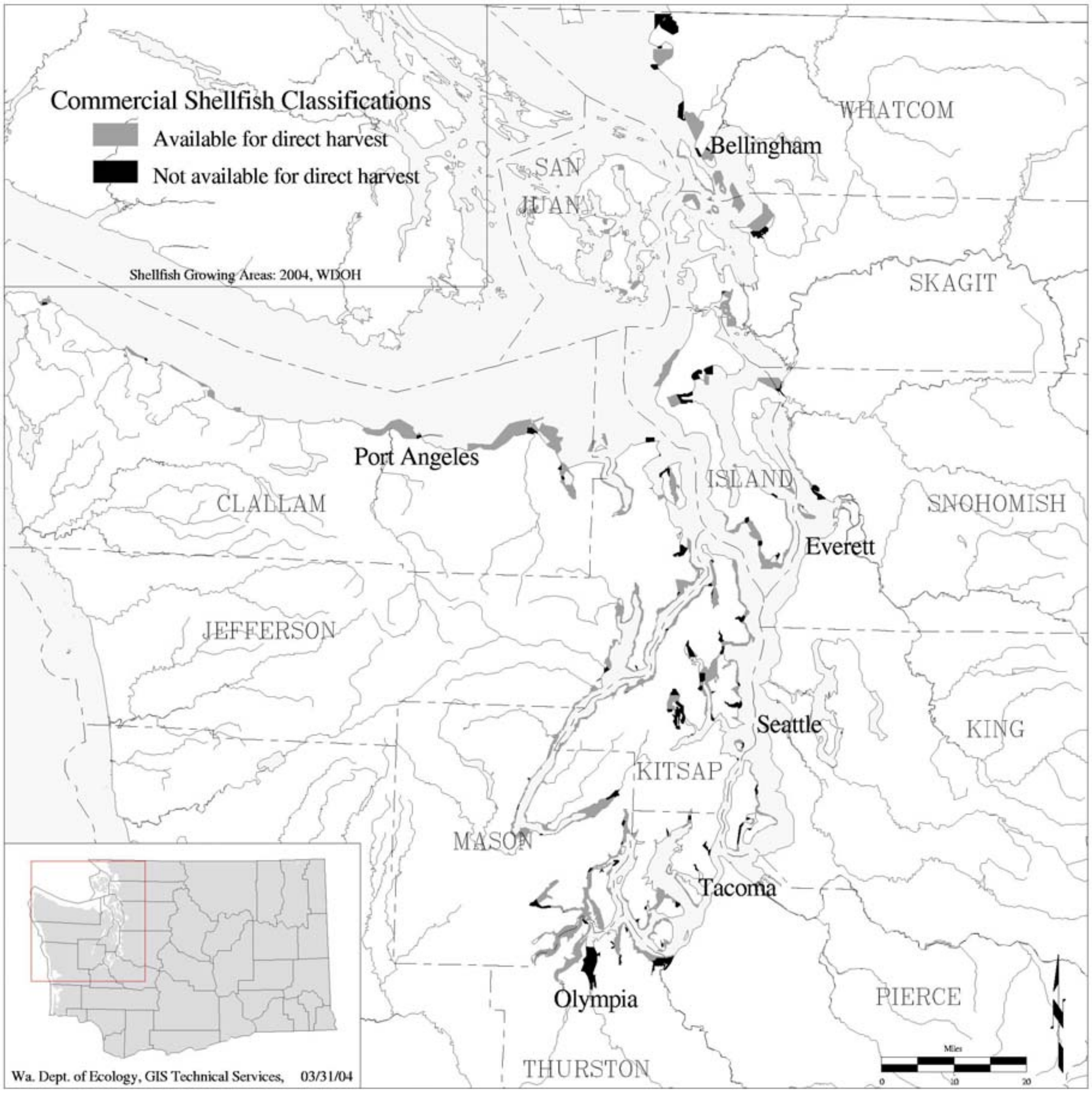
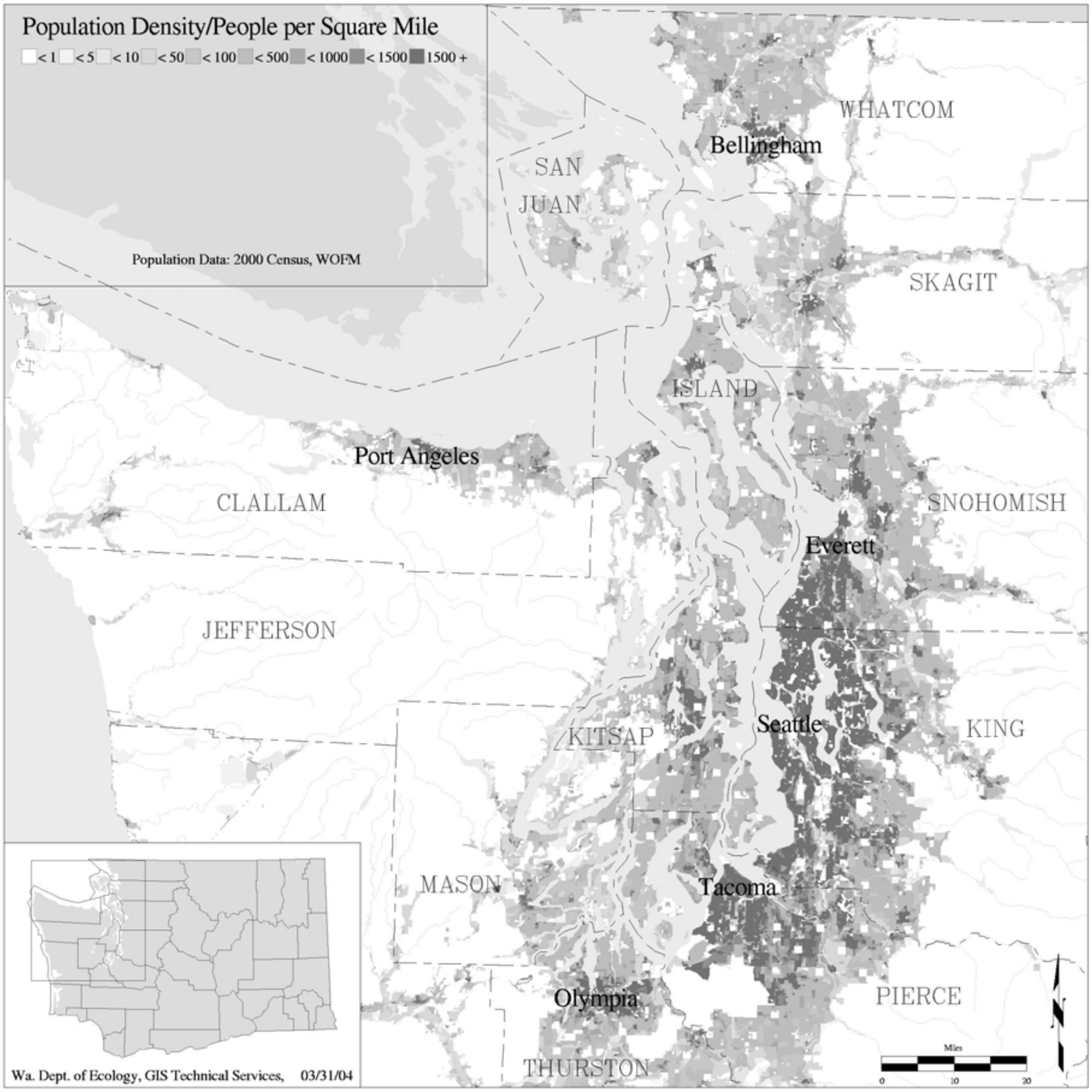


Figure 1: Classified commercial shellfish growing areas in Puget Sound. Areas available for direct harvest include *Approved* and *Conditionally Approved* classifications. Areas not available for direct harvest include *Restricted* and *Prohibited* classifications. All other marine areas not officially classified for commercial shellfish harvest are closed to commercial harvesting. (adapted from WDOH 2004)

and development while, at the same time, trying to preserve healthy coastal ecosystems. As expressed by Lipp *et al*. (2001a), “a fragile balance exists between the needs of coastal cities and communities and the health of aquatic systems” (p. 286). Historical assessments indicate limited success in this regard as researchers have documented significant impacts, including extensive degradation of shellfish growing areas and shellfish habitats, in all major coastal areas of the United States (Dame *et al.* 2000; Emmett *et al.* 2000; NRC 1994; NSTC 1995; Roman *et al.* 2000; POC 2003; Paul 2001; Turner 2001; USEPA 2001a; Walker *et al*. 2000).

Historical evaluations of these impacts also reveal changes in the nature of human settlement over time. Coastal urbanization is a relatively recent, worldwide phenomenon that differs dramatically from past periods of resource utilization and, more recently, industrialization (Vernberg and Vernberg 2001; Vernberg 1997). Current development and population trends pose unique and unprecedented environmental challenges, including the fact that urbanization imposes an imprint on the landscape that is very difficult to reverse (Dale *et al*. 2000). The related environmental impacts are often equally intractable. Scott *et al*. (1998) contend that the contamination and closure of shellfish growing areas is "perhaps the most significant, quantifiable impact from urbanization" (p. 1313).

In the Pacific Northwest, growth and development pose significant threats to the Puget Sound-Georgia Basin estuarine ecosystem of Washington State and British Columbia as measured by a number of environmental indicators (GBEI 2002; PSAT 2002a, 2002b). In Washington alone, two thirds of the state's 6 million people are concentrated around the shores of Puget Sound (Figure 2). The region's population continues to grow steadily at about 20 percent each decade and much of the fastest growth is occurring in the Sound's rural, shellfish-rich counties (WOFM 2002a). The current population of the Puget Sound-Georgia Basin region is approximately 7 million people and is expected to reach 9 million by 2020 (BC Stats 2002; WOFM 2002b).



Population Data: 2000 Census, WOFM

Wa. Dept. of Ecology, GIS Technical Services, 03/31/04

Figure 2: Puget Sound population density. (adapted from WOFM 2000)

These population figures closely mirror national and global trends as human populations continue to increase and concentrate in low-elevation coastal areas (Small and Cohen 2004). In the contiguous United States, coastal counties cover only 17 percent of the total land area yet are home to 53 percent of the nation's population, more than 148 million people. The nation's coastal population is expected to reach 165 million people—an average density of 327 people per square mile—by 2015 (NOAA 1998a; USDC 2001). Globally, approximately 37 percent of the world's population lives within 100 kilometers (62 miles) of the coastline and 50 percent within 200 kilometers (124 miles) (Cohen *et al*. 1997; Hinrichson 1999).

Population growth is only one aspect of the story. Land-cover change is the other. Development patterns have changed dramatically over the past century, even over the past couple of decades, as rural lands have been rapidly converted to urban and suburban uses (USEPA 2001b). Since 1982, land in the U.S. has been developed at more than twice the underlying rate of population growth and the gap between the two measures continues to widen (Beach 2002). Between 1982 and 1997 the amount of developed land—defined as the total urban area, built-up area, and transportation land—in the contiguous U.S. increased by 34 percent, from 73.2 million acres to 98.3 million acres. Developed land accounts for approximately 5.2 percent of the total land area in the contiguous U.S., but is unevenly concentrated in the eastern and coastal regions of the country (USDA 2001, 2000). A complementary land-cover analysis by Elvidge *et al*. (2004) estimated total impervious area[1] in the contiguous U.S. at 27.8 million acres. Based on current trends, development of the nation's coastal watersheds is expected to increase from 14 percent of the total land area in 1997 to over 25 percent by 2025 (Beach 2002). Beach (2002) explains that "if developed land were expanding at the same rate as population, coastal zone management would be a formidable task," but with "development vastly outstripping even the relatively high rate of population growth, the challenge is considerably greater" (p. 5).

Despite these findings, trends associated with the classification and condition of the nation's shellfish growing areas are not entirely negative. For example, the total area of coastal waters classified for commercial shellfish harvesting more than doubled between 1966 and 1995, due mainly to the classification of previously unclassified areas. The area approved for harvest also increased during the period from 8.1 to 14.9 million acres, although the total area approved for harvest declined as a percentage of the total classified area (NOAA 1998b, 1997a). Evaluation of the available data also reveals an interesting and important shift in pollution impacts. Nationally, harvest restrictions caused by industrial and municipal wastewater discharges, commonly called point source pollution, decreased while restrictions attributed to nonpoint source pollution increased, led by stormwater runoff (NOAA 1997a, 1997b). Nonpoint source pollution is also now the most common cause of shellfish classification downgrades in Puget Sound, reducing the region's commercially approved acreage by approximately 25 percent since 1980. Leading nonpoint pollution sources in the region include failing on-site sewage systems, farm animal wastes, and stormwater runoff (WDOH 2004; PSAT 2002b, 2000).

SHELLFISH SANITATION AND GROWING AREA CLASSIFICATIONS

Estuaries support many functions and uses, and no use is more dependent on clean water, more vulnerable to the effects of pollution and the transmission of disease, than the harvest and consumption of shellfish. Oysters, clams, and other bivalve molluscan shellfish feed by filtering plankton and other particles from the surrounding water and sediments, and in the process can accumulate disease-causing microorganisms (pathogens) and other contaminants that may be present in the nearshore environment.

Most waterborne pathogens originate in human and animal feces and include a wide variety of viruses, bacteria, and protozoa (Rose *et al*. 1999). The transmittal of viral disease is a key health concern associated with the consumption of shellfish. All of the known pathogenic viruses that present a significant public health threat in the marine environment are transmitted via the fecal-oral route and are known collectively as enteric viruses (Griffin *et al*. 2003). Lees (2000) points out that, of the many seafoods, "only the bivalve molluscan shellfish have consistently proven to be an effective vehicle for the transmission of viral disease" (p. 82). Noroviruses and Hepatitis A virus are most commonly implicated in shellfish-related disease outbreaks (Bosch 1998; Dadswell

---

[1] Impervious area, also called impervious surface or impervious cover, is defined as any surface in the urban landscape that cannot effectively absorb or infiltrate rainfall (CWP 2003). "Total impervious area" is often defined as the sum of all roads, parking lots, sidewalks, rooftops, and other impermeable surfaces (USEPA 2000) and generally does not take into account other nominally pervious surfaces, such as lawns, or the hydraulic connection between the surfaces and the drainage system. "Effective impervious area" is defined as the impervious surface that is hydraulically connected to the downstream drainage system (Booth and Jackson 1997). Impervious area is not synonymous with "developed land" because impervious surfaces cover only a portion of developed area. The impervious cover of single-family residential development, for example, is estimated at about 40 percent of the developed area (Beach 2002).

1993; Geldreich 1978; Griffin *et al*. 2003; Lees 2000; Lipp and Rose 1997; NRC 1999, 1993; Richards 1987; Sair *et al*. 2002; Stelma and McCabe 1992; Vasconcelos 2001).

Most health risks associated with the consumption of shellfish and other seafoods are attributed to the environment where the products are grown and harvested (NRC 1991). To address these risks all commercial shellfish growing areas are monitored and classified under the National Shellfish Sanitation Program (NSSP). The main assessment tool of the NSSP is the comprehensive sanitary survey. Surveys are conducted on a regular basis for all commercial growing areas and consist of ongoing water quality monitoring (principally measurements of fecal coliform bacteria[2]), pollution source investigations, and meteorological and hydrographic evaluations (USFDA 2000). Shellfish areas not meeting the sanitary standards of the NSSP are closed to harvest. In Puget Sound, the Washington Department of Health conducts additional monitoring studies and data assessments under the *Puget Sound Water Quality Management Plan* to support broad-based efforts to protect and restore water quality for shellfish harvesting in the region (PSAT 2000).

Because of the difficulty and expense associated with the direct detection of pathogens, fecal coliform bacteria are widely used as indicator organisms to signal the possible presence of feces and pathogenic organisms. While bacterial indicators have proven useful in helping to assess the sanitary condition of shellfish growing areas, there is growing recognition that they do not reliably predict the occurrence and survival of enteric viruses and other pathogens in the marine environment (Bosch 1998; Goyal *et al*. 1984; Hernroth *et al*. 2002; Jiang *et al*. 2001; Lees 2000; Lilja and Glasoe 1993; Lipp and Rose 1997; NRC 1993, 1999, 2004; Noble *et al*. 2003a; Noble and Furmen 2001; Schroeder *et al*. 2002; USEPA 2001c; Wetz *et al*. 2004; Vasconcelos 2001). Other factors further complicate the indicator system and the task of accurately gauging growing-area conditions and related health risks. These include variability in sampling procedures as well as unique geographic, hydrographic, and anthropogenic factors such as climate and weather patterns, circulation patterns and water properties, watershed hydrology and geology, land cover and land use patterns, pollution sources and management practices, and population densities and patterns (Bennett *et al*. 2000; Boehm *et al.* 2002; De Luca-Abbott *et al*. 2000; Henrickson *et al*. 2001; Leecaster and Weisberg 2001; Lipp *et al*. 2001b; NRC 1993, 2004; Noble *et al.* 2003b, 2001; Rose *et al*. 2001a, 2001b; Smith *et al*. 2001). Any discussion of the relationship between coastal development and microbial contamination of shellfish growing areas must acknowledge and account for these factors and uncertainties.

EFFECTS OF URBANIZATION ON WATERSHED HYDROLOGY AND WATER QUALITY

Aquatic habitats are integral parts of the natural landscape, shaped and defined by many interacting physical, chemical, and biological processes over time and space (Hynes 1975; Karr 1998; Naiman *et al.* 1992; Spence *et al*. 1996; Turner 1994). Numerous studies have shown that human modification of the natural landscape has a direct and significant effect on the condition of aquatic systems, including both stream systems (Alberti *et al*. in press; Bolstad and Swank 1997; Booth 1991; Booth and Jackson 1997; Bunn and Arthington 2002; Hunsaker and Levine 1995; Klein 1979; May *et al.* 2000; Nelson and Booth 2002; Paul and Meyer 2001; Poff *et al*. 1997; Roth *et al.* 1996; Snyder *et al*. 2003; Wang *et al*. 2001; Wear *et al*. 1998) and nearshore marine systems (Bay *et al*. 2003, 1999; Bowen and Valiela 2001; Breitburg *et al.* 2003; Dojiri *et al*. 2003; Holland 2000; Holland *et al.* 2004, 1998; Hopkinson and Vallino 1995; Lerberg *et al*. 2000; Mallin *et al*. 2001, 2000a, 2000b; Mallin and Lewitus 2004; Sanger *et al*. 1999a, 1999b; Valiela *et al*. 1992; Van Dolah *et al*. 2000; Vernberg *et al*. 1999, 1996, 1992; Vernberg and Vernberg 2001). Primary impacts include the fragmentation and loss of habitats as well as the degradation of water resources and water quality (USEPA 2001b). For shellfish resources, both types of impacts are relevant and important and are best explained in a landscape context.

---

[2] The two-part water quality standard for shellfish growing areas is based on 30 or more samples per sampling station and requires (1) a geometric mean ≤ 14 MPN/100 ml (applied in all shellfish growing areas) and (2) a 90th percentile value ≤ 43 MPN/100 ml (applied in areas where nonpoint sources of pollution are present) or no more than 10 percent of the results > 43 MPN/100 ml (applied in areas where point sources of pollution are present). MPN means "most probable number" and represents a single fecal coliform bacterium (PSAT 2002b; USFDA 2000).

Microorganisms are discharged to shellfish growing areas from a variety of pollution sources along three main pathways: (1) direct discharges from sewage outfalls, boaters, marine mammals, and other sources; (2) subsurface flows from such sources as shoreline on-site sewage systems; and (3) overland flows in the form of stormwater runoff, stream flows and other surface runoff. These sources and pathways are determined by a variety of human activities and land uses that tend to exert a progressively greater influence on the landscape and environmental conditions as development intensifies over time. Although bacterial loadings and shellfish impacts generally correlate with the intensity of adjacent land uses, it is important to note that shellfish growing areas can be contaminated and closed in areas with limited development if raw sewage or animal wastes are being discharged to the waters. Examples of such closures in relatively rural areas of Puget Sound include Lilliwaup Bay (elk and other wildlife), Dosewallips River delta (harbor seals), and Similk Bay (residential sewage discharges) (Faigenblum *et al*. 1988; WDOH 2000, 1998; WPRC 1993). By its very nature, nonpoint source pollution presents risks that must be addressed in all shellfish areas, regardless of the degree of development. The transformation of landscapes from rural to urban land uses simply compounds the problem.

Leopold (1968) contends that "of all the land use changes affecting the hydrology of an area, urbanization is by far the most forceful" (p. 1). Flow regime[3] is a central issue and a defining feature of watershed hydrology. Flow regime refers to the distribution and movement of water in a particular stream or region and is viewed as a master variable governing the character and integrity of aquatic systems (Karr 1998; Poff *et al*. 1997). Changes in flow regime begin with the "first expression of human activity in a watershed" and then progress as development increases in scope and scale (Booth *et al*. 2001, p. 56; Booth 2000; CWP 2003; Poff *et al*. 1997; Schueler 2000a, 2000b). In the Pacific Northwest, "the fundamental hydrologic effect of urban development is the loss of water storage in the soil column" (Booth 2000, p. 3). As forests are cleared and soils are stripped, compacted, and covered over with roads, buildings, and other impervious surfaces, precipitation that was previously taken up by vegetation or that moved slowly into and through the soil layer as subsurface flow is now converted to overland flow. The landscape's natural capacity to absorb and attenuate flows and contaminants is further reduced as other features of the terrain are ditched, drained, armored, and straightened to shed runoff as quickly and efficiently as possible (Booth and Jackson 1997; CWP 2003; Mallin *et al*. 2001, 2000a; Schueler 2000b, 2000c). This combination of reduced retention and enhanced conveyance results in greater runoff volumes, lower stream baseflows, more stormflow events, and higher peak streamflows that rapidly rise and recede (Booth 1991; Corbett *et al*. 1997; CWP 2003; Konrad and Booth 2002, 2001; Leopold 1968; Poff *et al*. 1997; Schueler 2000a, 2000b) (Figure 3). Related impacts to property and water resources include increased flooding, degraded stream channels and other habitats, reduced groundwater recharge, degraded water quality, and polluted shellfish beds and swimming beaches (Booth 2000; Booth *et al*. 2002; Booth and Jackson 1997; Burton and Pitt 2002; Dwight *et al*. 2002; Eisele *et al*. 2001; Griffin *et al*. 2003; Haile *et al*. 1999; Henrickson *et al*. 2001; Konrad and Booth 2002, 2001; Mallin *et al*. 2001, 2000a, 2000b; Mallin and Lewitus 2004; May *et al*. 2000; Noble *et al*. 2000a, 2000b; Pitt 2000a; RIDEM 2004a;

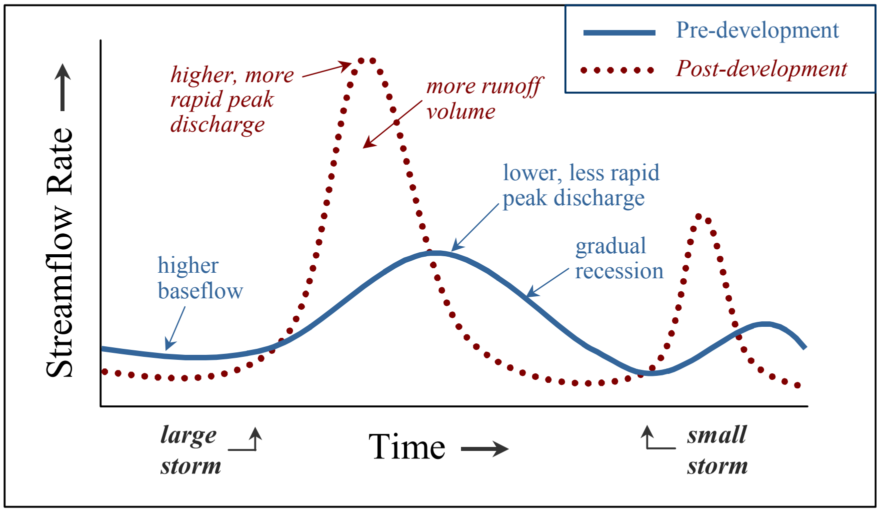


Figure 3: Altered stream hydrograph in response to urbanization. (adapted from Schueler 2000a, 1987; CWP 2003)

---

[3] Flow regime is characterized by the magnitude, frequency, duration, timing, and rate of change in water discharges (Poff *et al*. 1997). Flow regime is one of five main water resources features altered by the cumulative effects of human activities. The other four are physical habitat structure, water quality, energy sources (e.g., food sources), and biotic interactions (Booth *et al*. 2001; Karr 1998).

Schueler 2000a, 2000c; Tourbier and Westmacott 1981; Weiskel *et al*. 1996). Mallin *et al*. (2001) explains that these impacts are accentuated in coastal shellfish watersheds because "shellfishing beds are often located within meters of developed land and much of the stormwater runoff reaching these areas does not receive any pretreatment before entering the estuaries" (p. 189).

Stormwater runoff is a defining characteristic of urbanizing landscapes—an almost unavoidable byproduct of concentrated human development. Among the many management challenges, stormwater runoff presents a complicated pollution problem that can readily offset gains achieved in controlling other pollution sources as development progresses. A good example of this involves the conversion from decentralized on-site sewage treatment to centralized municipal sewage treatment, which is generally undertaken to protect public health and improve water quality. While the construction of municipal sewage systems can achieve marked improvements in sewage treatment, such systems are often constructed to accommodate added growth which, in turn, tends to generate more runoff and related stormwater impacts. Illustrating this point, Young and Thackston (1999) documented higher fecal bacteria concentrations in streams in more densely developed, sewered watersheds than in unsewered watersheds with comparable land use/land cover characteristics. The North Carolina Coastal Federation (2002) goes so far as to say that with "sewers and shellfish you can't easily have both . . . unless those building the sewer go to great lengths to control the poisoned runoff that the sewer will inevitably bring" (p. 8).

Comprehensive stormwater monitoring studies have reported mean fecal coliform concentrations ranging from 5,000 to 22,000 colonies per 100 milliliters in stormwater discharges, with concentrations varying as much as five orders of magnitude at individual sampling sites (CWP 2003; Pitt *et al*. 2004; Schueler 2000c; USEPA 2002a). Studies have also documented high levels of selected pathogens in stormwater discharges (Burton and Pitt 2002). Fecal coliform concentrations are influenced by such factors as rainfall and drainage area characteristics, including land uses, fecal pollution sources, and runoff potential of different surfaces and landscapes (Burton and Pitt 2002; Pitt 2000b). Illustrating the importance of source-area characteristics, Pitt *et al*. (2004) reported average fecal coliform concentrations of 7,750 for residential areas, 4,500 for commercial areas, and 2,500 for industrial areas. Pollution sources that can potentially contribute to stormwater contamination include cross connections with sewage lines, failing on-site sewage systems, pet and other animal wastes, and even bacterial growth within the drainage system itself. None of the potential sources is benign and the cumulative loadings can be immense. Dog feces, for example, has been estimated to contain 23 million fecal coliform bacteria per gram (van der Wel, 1995; Schueler 2000c) and pet wastes have been identified as key pollution sources in many shellfish contamination studies (Kelsey *et al*. 2003, 2004; Mallin *et al.* 2001; Van Dolah *et al*. 2000; Weiskel *et al*. 1996; White *et al*. 2000). More broadly, numerous other studies have identified stormwater runoff and stream flows associated with rainfall events as major sources of coastal microbial pollution (Ackerman and Weisberg, 2003; CRWQCB 2004; De Luca-Abbott *et al*. 2000; Dwight *et al.* 2002; Eisele *et al*. 2001; Lipp *et al*. 2001b; Marchman 2000; Macfarlane 1996; NRC 1999, 1993; Noble *et al*. 2000a, 2000b; Pitman 1995; RIDEM 2004a).

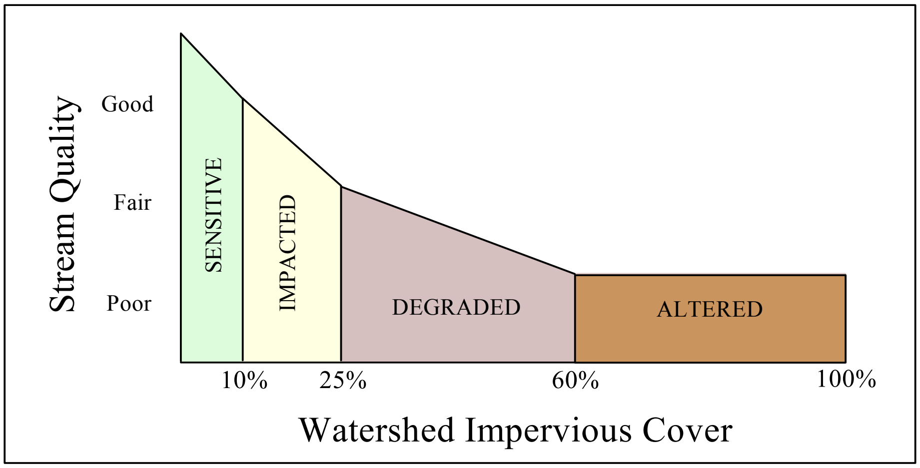
Microbial Pollution in Stormwater

"Microbes are problematic. They are small and include hundreds of groups, species, biotypes and strains. They are ubiquitous in the environment, found on nearly every surface of the earth. They exist within us, on us, on plants, soils and in surface waters. They grow rapidly, die-off, survive or multiply depending on a changing set of environmental conditions. Some microbes are beneficial to humans, while others exert no impact at all. Other microbes cause illness or disease, and a few can even kill you. The presence of some types of microbes indicates a potential risk for water contamination, while other microbes are pathogenic themselves. Microbes are nearly always present in high concentrations in stormwater, but are notoriously variable. They are produced from a variety of watershed sources, such as sewer lines, septic systems, livestock, wildlife, waterfowl, pets, soils and plants, and even the urban drainage system itself. It is little wonder that many watershed managers are thoroughly confused by the microbial world."

Schueler 2000c, p. 74

A variety of landscape indicators and assessment techniques have been used to correlate watershed development and impacts on aquatic systems, with the most extensive research focusing on stream systems. Landscape indicators that have been tested include population, land cover, development patterns, wetland cover, riparian buffer widths, road crossings, road densities, on-site sewage system densities, housing densities, and impervious cover (Arnold and Gibbons 1996; Bolstad and Swank 1997; Brown 2000; CWP 2003; Gergel *et al.* 2002; Johnson and Gage 1997; May *et al.* 2000; McBride 2001; Morse *et al.* 2003; Smith *et al.* 2001; Vølstad *et al.* 2003; Young and Thackston 1999). Studies correlating urbanization with stream bacterial levels include Bolstad and Swank (1997), Hydroqual (1996), and Young and Thackston (1999).

The relationship between stream health and impervious cover has been studied most thoroughly, revealing that impervious cover is closely associated with a continuous but variable decline in most stream-health indicators and leading to the formulation of an "impervious cover model" (CWP 2004, 2003) (Figure 4). While the model has strong scientific underpinnings, it represents a relatively simple index of human activity and related stream-system impacts. Application of the model should take into consideration a number of generalizations and cautions (CWP 2003; Booth *et al.* 2001). For example, the breakpoints in stream conditions at 10 and 25 percent impervious cover do not represent *thresholds* as much as they reflect *transitions* based on a composite of different stream-health indicators (CWP 2003). Booth *et al.* (2002) underscore this point by explaining that certain stream indicators, particularly biological indicators, demonstrate a continuum of effects rather than threshold behavior and that a wide range of stream conditions can be associated with any given level of imperviousness, particularly at lower levels of development.



Selected Indicators of Stream Health	Impacted (10-25% IC)	Degraded (25-60% IC)	Altered (60-100% IC)
Stormwater Runoff as Fraction of Annual Rainfall	10 to 30%	25 to 60%	60 to 90%
Fraction of Original Stream Network Remaining	60 to 90%	25 to 60%	10 to 30%
Fraction of Intact Riparian Forest Buffer	50 to 70%	30 to 60%	less than 30%
Violations of Bacteria Standards	frequent violations during wet weather	continuous violations during wet weather, episodic violations during dry weather	continuous violations during wet weather, frequent violations during dry weather

Figure 4: Impervious cover model and selected indicators of stream health. (adapted from CWP 2004, 2003)

Researchers have conducted similar studies to assess the effects of development on nearshore systems and have identified equally strong correlations. For example, studies of tidal creek systems in South Carolina by Lerberg *et al.* (2000) documented severe hypoxia, broad salinity fluctuations, potentially toxic levels of contaminated sediments, and low macrobenthic diversity and abundance in watersheds with greater than 50 percent impervious cover. In watersheds with 15 to 35 percent impervious cover, these effects were more muted but still showed signs of degradation associated with hypoxia, salinity fluctuations, and increased prevalence of stress-tolerant species. Related research by Holland *et al.* (2004) identified human population density and associated increases in impervious cover as the "ultimate stressor" on tidal creek systems (p. 151). The researchers documented adverse changes in physical-chemical processes (e.g., increased fecal coliform loadings, altered sediment characteristics, increased chemical contaminants) when impervious cover reached 10 to 20 percent in the adjacent drainage basins, and degraded biological resources (e.g., reduced abundance of stress-sensitive organisms, closed shellfish beds, altered food webs) when impervious cover reached 20 to 30 percent (Holland *et al.* 2004; Holland and Sanger 2001; Holland 2000). Mallin *et al.* (2000a) also correlated impervious cover with bacterial levels in shellfish growing areas of coastal North Carolina and found acceptable water quality for shellfish harvesting in watersheds with less than 10 percent impervious cover, impaired water quality in watersheds with 10 to 20 percent impervious cover, and highly degraded conditions above 20 percent. White *et al.* (2000), in contrast, documented bacterial contamination and shellfish closures in another North Carolina watershed with less than 5 percent impervious cover. The researchers attributed the impacts mainly to hydrologic modifications in the watershed (e.g., channeling and bulkheading) and high connectivity between the pollution sources and shellfish beds. Taken together, these findings indicate that bacterial concentrations and other measures of estuarine health are strongly associated with impervious cover, and that shellfish areas are vulnerable to contamination at low levels of development if the fecal loadings are not adequately treated or buffered. The findings also suggest that more research is needed to better understand these relationships before it might be possible to champion a "ten-percent rule" for impervious cover as an environmental threshold or management standard in coastal protection programs (see, for example, Beach 2002; Funders' Network 2004; Walsh 2002).

FIELD STUDIES OF URBANIZATION AND SHELLFISH CONTAMINATION

The contamination and closure of shellfish growing areas are two of the more tangible and, to some extent, predictable environmental impacts associated with coastal urbanization. Vernberg and Vernberg (2001) assert that "the greatest concentrations of bacterial contamination lie at the interface of the land and sea and can be linked directly to upland population" (p. 102). This observation helps explain one the fundamental conflicts associated with the use of land and water resources in the coastal environment.

Many studies have been conducted in recent years addressing the causes, effects, and recommended actions to control microbial pollution in coastal areas, including a growing number of total maximum daily load (TMDL) studies (see, for example, CRWQCB 2004; Joubert and Lucht 2000; MDEP 2002; MDEQ 2002; NYDEC 2003; ODEQ 2001; RIDEM 2004a; VDEQ 2003; WDOE 2004). While such studies are informative to the broader topic of bacterial contamination in the coastal environment, this section of the literature review focuses more narrowly on studies correlating development with coastal bacterial contamination, and even more specifically on studies correlating coastal development with the contamination and closure of shellfish growing areas. The selected studies have been carried out in different parts of the country using a variety of research approaches and techniques over the past two decades. A majority of the work has occurred in the eastern United States, and perhaps the best and most extensive correlation studies have been conducted in the coastal areas of North Carolina and South Carolina as a result of several multidisciplinary research programs examining the effects of urbanization on coastal ecosystems, including the *Tidal Creeks Program*, *Urbanization and Southeastern Estuarine Systems* (USES), and *Land Use-Coastal Ecosystem Study* (LU-CES).

Early work by Maiolo and Tschetter (1981) evaluated the relationship between population growth, bacterial contamination, and shellfish closures over a 27-year period in New Hanover and Carteret counties in North Carolina. The researchers correlated population increases in the two counties with degraded water quality, shellfish closures, and reduced shellfish landings in the adjacent estuaries. The authors attributed the impacts mainly to growth that had outstripped the region's sewage management capacity and used the results to forecast shellfish closures and economic losses that could be expected with continued population increases in the region.

Duda and Cromartie (1982) assessed coastal North Carolina watersheds during the same period and also documented sharp increases in residential development and corresponding shellfish closures. Their analysis strongly correlated bacterial levels with on-site sewage system densities and identified stormwater runoff from impervious surfaces as a contributing factor in more urbanized watersheds. Most of the sewage systems were installed in areas with poor soils that were then ditched and drained to "overcome the limitations of these unsuitable soils" (p. 1273). Unfortunately these modifications only exacerbated the pollution impacts by increasing hydraulic connectivity and allowing the failing sewage systems to drain more efficiently to the adjacent tidal creeks. The researchers determined that on-site sewage system densities greater that one system per seven acres resulted in shellfish closures. Recommendations for remedying the situation focused on better sewage management as well as revegetation, restoration, and protection of natural drainage features.

More recent research by Mallin *et al.* (2001, 2000a) examined the effects of development on some of these same tidal creeks in North Carolina between the years 1984 and 1997. The study period followed the completion of major sewage infrastructure projects in the early 1980s and allowed for broader evaluation of nonpoint pollution impacts. On a regional scale the researchers found significant correlations between population growth and shellfish closures. Watershed-scale assessments of five tidal creeks in New Hanover County correlated bacterial levels with population, more strongly with percent developed land, and even more strongly with percent impervious cover (Figure 5). Watersheds with less than 10 percent impervious cover had generally good water quality and large areas open to shellfish harvesting; watersheds with 10 to 20 percent impervious cover had impaired water quality and shellfish closures in the upper portions of the creeks; and watersheds with greater than 20 percent impervious cover had severely polluted waters with all areas of the creeks closed to shellfish harvesting (Mallin *et al.* 2001, 2000a). The researchers also evaluated the effects of rainfall on water quality in 11 coastal plain streams, strongly correlating rainfall events with fecal coliform counts and turbidity except in watersheds with extensive wetland cover. The findings highlight the combined importance of limited impervious cover and intact vegetation and wetland systems for mitigating microbial contamination of coastal waters.

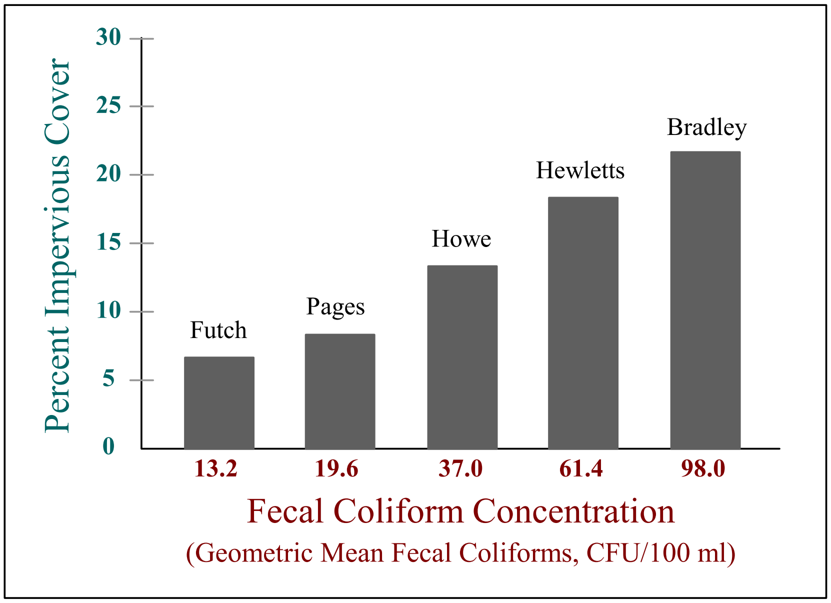
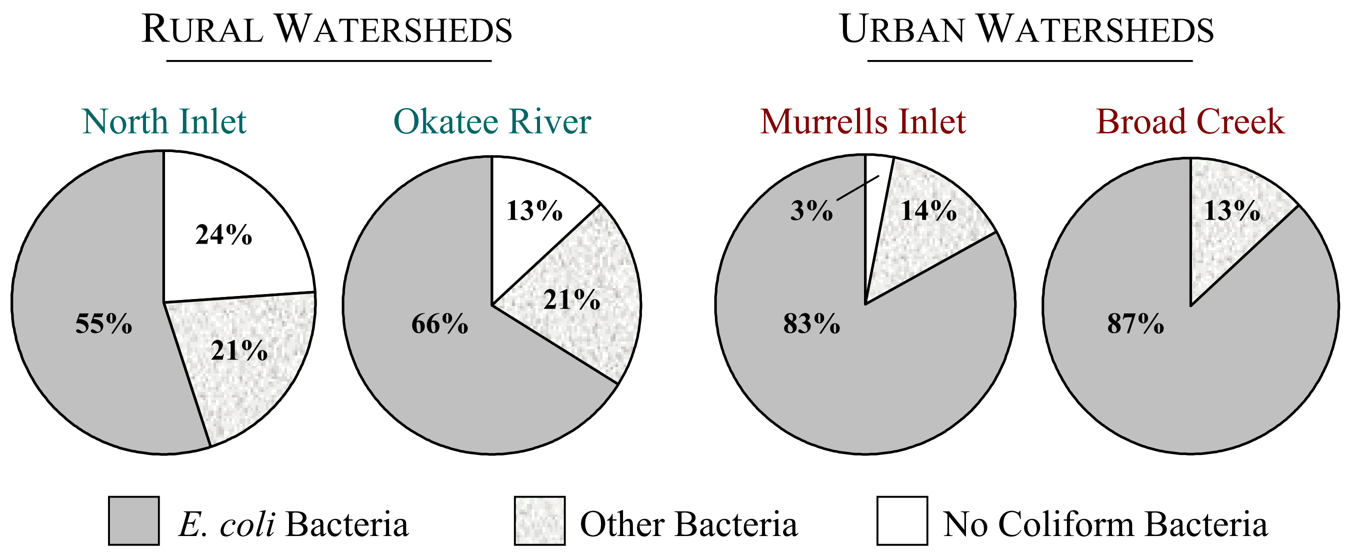


Figure 5: Percent watershed impervious cover and corresponding fecal coliform concentrations in five tidal creeks, New Hanover County, North Carolina. (adapted from Mallin *et al.* 2001)

Research by White *et al.* (2000, 1998) in the Jumping Run Creek watershed of Carteret County, North Carolina, further underscores the influence of watershed hydrology on estuarine water quality. Although population increases in this small, 800-acre coastal watershed coincided with shellfish closures in the adjacent waters, bacterial loadings did not correlate with other landscape indicators such as developed area or impervious area, which covered less than five percent of the watershed. Instead, the researchers documented a strong relationship between bacterial levels and extensive ditching, bulkheading, and channeling in the watershed. Because of the hydrologic modifications, runoff that once took days or even weeks to pass through the native pocosin wetlands now moved in greater volumes and reached the shellfish beds in hours, allowing little time for natural reduction and die-off of the microorganisms. The researchers identified pet and wildlife wastes and possible subsurface flows from on-site sewage systems as the main pollution sources. Recommendations for reducing the contamination focused on riparian buffer restoration, wetland construction, stormwater treatment, and public education.

In coastal South Carolina, scientists affiliated with the USES research program have employed a variety of techniques to monitor and compare land uses and ecosystem responses in highly urbanized Murrells Inlet and relatively undeveloped North Inlet (Kelsey *et al.* 2003, 2004; Scott *et. al.* 1996, 1998; Vernberg and Vernberg 2001; Vernberg *et al.* 1999, 1996, 1992; White *et al.* 2004). Among other findings, the researchers reported that 67 percent of the sampling stations in Murrells Inlet did not meet water quality standards for shellfish harvesting compared to 33 percent in North Inlet. Murrells Inlet also had higher occurrences of *E. coli* bacteria, fewer coliform-free stations, and fewer bacterial species comprising the coliform group—findings that the researchers attributed to urban influences and higher densities of on-site sewage systems in the Murrells Inlet watershed (Vernberg *et al.* 1996; Scott *et al.* 1998; Chestnut *et al.* 2000). Subsequent analysis of Murrells Inlet by Kelsey *et al.* (2004, 2003) identified concentrations of on-site sewage systems, rainfall events, and runoff from urban areas as key predictors of fecal coliform levels. However, further evaluations using geographic information system (GIS) techniques, regression analysis, and multiple antibiotic resistance (MAR) analysis (a microbial source-tracking technique) suggested that the majority of fecal contamination came from pets and other non-human sources. The researchers concluded that "the major source of pollution in Murrells Inlet appears to be stormwater runoff, particularly from urban areas" and the “study clearly shows the impacts of human activities on fecal pollution in Murrells Inlet” (Kelsey 2003, p. 345-346). The researchers highlighted the need to reduce and intercept urban runoff, clean up pet wastes, and eliminate boater waste discharges to reduce the bacterial levels.

Comparative analysis of land uses and estuarine conditions in the Okatee River and Broad Creek watersheds (15 and 32 percent impervious cover, respectively) in nearby Beaufort County, South Carolina, has yielded similar results. As part of a comprehensive environmental assessment, researchers used conventional monitoring techniques, MAR analysis, and analytical profiling index (API) biotyping to document higher bacterial concentrations, fewer coliform-free sampling sites, and a higher percentage of antibiotic-resistant *E. coli* strains (indicative of human sources) in the more urbanized Broad Creek watershed (Chestnut *et al*. 2000; Webster *et al*. 2004). High percentages of MAR-negative sampling stations in the two waterbodies suggested that animal sources were major contributors in both areas. The researchers also noted that “the inclusion of green space corridors is important in maintaining the assimilative capacity of the tidal creek watersheds” (Chestnut *et al*. 2000, p. 33). Recommendations for reducing bacterial loads in the two watersheds included better sewage management, comprehensive surface water management (including enhanced buffers, reduced impervious cover), increased public education on pet and other animal wastes, and better handling of marina and boater wastes (Van Dolah *et al*. 2000). When combined with findings from Murrells Inlet and North Inlet, bacterial profiles for the four waterbodies reveal similarities between the two more rural watersheds, North Inlet and Okatee River, and the two more urban watersheds, Murrells Inlet and Broad Creek (Chestnut *et al*. 2000) (Figure 6).



note: increased occurrence of E. coli bacteria and decreased occurrence of coliform-free samples characterize increased urbanization

Figure 6: Percentage of bacterial species in water samples from four South Carolina estuarine systems using analytical profiling index (API) biotyping. (adapted from Chestnut *et al.* 2000)

In many areas of Florida, including Apalachicola Bay, Charlotte Harbor, Tampa Bay, Sarasota Bay, and the Florida Keys, researchers have documented widespread and chronic microbial contamination caused by coastal development (Griffin *et al*. 1999; Lipp *et al*. 2002, 2001a, 2001b; Lipp and Rose 2001; Marchman 2000; Rose *et al*. 2001a). In Apalachicola Bay—site of approximately 90 percent of the state’s oyster harvest—Marchman (2000) identified extensive nonpoint pollution in the lower Apalachicola River watershed and correlated bacterial loadings with rainfall events, river flows, and urbanization. The analysis also identified impervious surfaces, deteriorating infrastructure, poor ground cover, inadequate pollution controls, and inappropriate land uses as contributing factors. In Charlotte Harbor, Lipp *et al.* (2001b) studied the spatial and seasonal distribution of fecal coliform bacteria and enteric pathogens and documented higher concentrations of fecal bacteria in areas of low salinity (greater freshwater influence) and high on-site sewage system densities. The researchers strongly correlated fecal indicator organisms with rainfall, streamflow, and cooler water temperatures. Studies of Sarasota Bay also documented a strong relationship between on-site sewage system densities and bacterial levels, and determined that subsurface flow was a primary transport mechanism for the contaminants (Lipp *et al*. 2001a). Lipp and Rose (2001) concluded that "these studies reveal a high level of pollution in tidally influenced streams and canals of southwest Florida and highlight the importance of physical factors such as tides, surface runoff and streamflow in the distribution of human pathogens in coastal areas" (p. 1).

Coastal development and microbial contamination have also received significant attention in the New England states. An assessment of bacterial sources, pathways, and loadings in the Buttermilk Bay watershed of Massachusetts by Weiskel *et al*. (1996) concluded that waterfowl and surface flows (storm drains and streams) accounted for most of the bay's annual bacterial load at 67 and 24 percent, respectively, with lesser inputs attributed to beach wrack (shoreline vegetation), sediment resuspension, and subsurface flow from on-site sewage systems. Although the waterfowl load was substantial, related effects appeared to be mitigated by seasonal and spatial distribution and other factors. In contrast, surface runoff carrying feces from domestic pets and wildlife had a disproportionately high impact on nearshore bacterial levels. Bacterial concentrations in stormwater flows averaged 10,000 colonies per 100 milliliters and accounted for two thirds of the surface-flow load. The bacterial concentrations correlated strongly with urban land uses, especially high-density residential development. Bacterial yields from impervious surfaces served by storm drains were 300-8,000 times higher than from low-intensity land uses drained by streams. Among other recommendations, the researchers recommended that direct stormwater discharges to coastal waters should be prevented and the runoff should be redirected to the groundwater pathway to capitalize on the soil's natural capacity to attenuate the contaminants (Weiskel *et al*. 1996).

Stormwater remediation projects in shellfish growing areas of New England

GREENWICH BAY, WARWICK, RI: Nutrient, sediment, and bacterial reduction using Vortechs™ systems with detention basins and vegetated swales.
www.pollutionengineering.com/CDA/ArticleInformation/features/BNP__Features__Item/0,6649,103950,00.html

BUTTERMILK BAY, BOURNE/WAREHAM, MA: Storm drain retrofits using catch basins and infiltration structures (leaching chambers and galleys).
www.buzzardsbay.org/buttfact.htm

SPRAGUES COVE, MARION, MA: Constructed wetland system consisting of settling basin, shallow marsh, deep pond, and second shallow marsh.
www.buzzardsbay.org/sprafact.htm

BROAD MARSH RIVER, WAREHAM, MA: Retrofits using two types of subsurface infiltration structures (concrete galleys and plastic chambers).
www.buzzardsbay.org/download/bmrfinal.pdf &
www.epa.gov/owow/nps/Section319III/MA.htm#1

MEETINGHOUSE POND AND TOWN COVE, ORLEANS, MA: Four retrofits using subsurface settling tanks and leaching chambers, and one filter-dam retrofit consisting of concrete tanks and sand/geotextile filter media.
http://estuaries.olemiss.edu/cdrom/ESTU1996_19_2A_311_319.pdf
www.epa.gov/owow/watershed/Proceed/bingham.htm

IPSWICH BAY, IPSWICH, MA: Use of various treatment systems, including constructed wetlands, infiltration systems, retention basins, grass swales, and such commercial techniques as Vortechs™, StormTreat™ , and Downstream Defender™ systems.
www.naturecompass.org/8tb/news/9802_storm.html

LAKE TASHMOO, TISBURY, MA: Installation of 12 leaching basins consisting of cement vault filled with limestone, covered by oil-absorbing pads and surrounded by gravel bed to capture and treat road runoff.
www.epa.gov/owow/nps/Section319III/MA.htm#2

In nearby Cape Cod, rapid coastal development has caused extensive shellfish closures attributed primarily to bacterial contamination from stormwater runoff, on-site sewage systems, and wildlife (Macfarlane 1988). In the Town of Orleans, resource managers identified stormwater discharges as the main pollution problem and retrofitted the town's five largest drainages with stormwater treatment systems to reduce bacterial loadings to the shellfish beds. The treatment systems achieved substantial reductions in bacterial concentrations and the shellfish beds were subsequently reopened to harvest (Macfarlane 1997, 1996, 1988; Bingham *et al.* 1996). Similar stormwater remediation approaches have been employed in other coastal areas of New England using a variety of treatment systems. These projects have achieved mixed results but have generally proven effective in helping to reduce bacterial loads when the systems are properly designed, installed, and maintained (Castonguay 1998; Krahforst *et al.* 2002; Taber and Costa 1998; USEPA 2002b).

A total maximum daily load (TMDL) assessment of Greenwich Bay, Rhode Island, illustrates the dramatic effect stormwater discharges and other surface runoff can have on coastal waters and their suitability for shellfish harvesting. The TMDL assessment characterized land uses in the watershed as predominantly urban residential and identified more than 150 stormwater discharges along the shores and tributary streams. During dry weather conditions, all sampling stations in Greenwich Bay and adjacent coves met the geometric mean water quality standard for shellfish harvesting, and all but five stations met the accompanying 90th percentile standard. Following rain events, only one station met both parts of the shellfish water quality standard (Figure 7). Based on these correlations, Greenwich Bay was classified as *Conditionally Approved* to prohibit the harvest of shellfish for seven days following precipitation events of 0.5 inches or more (RIDEM 2004a).

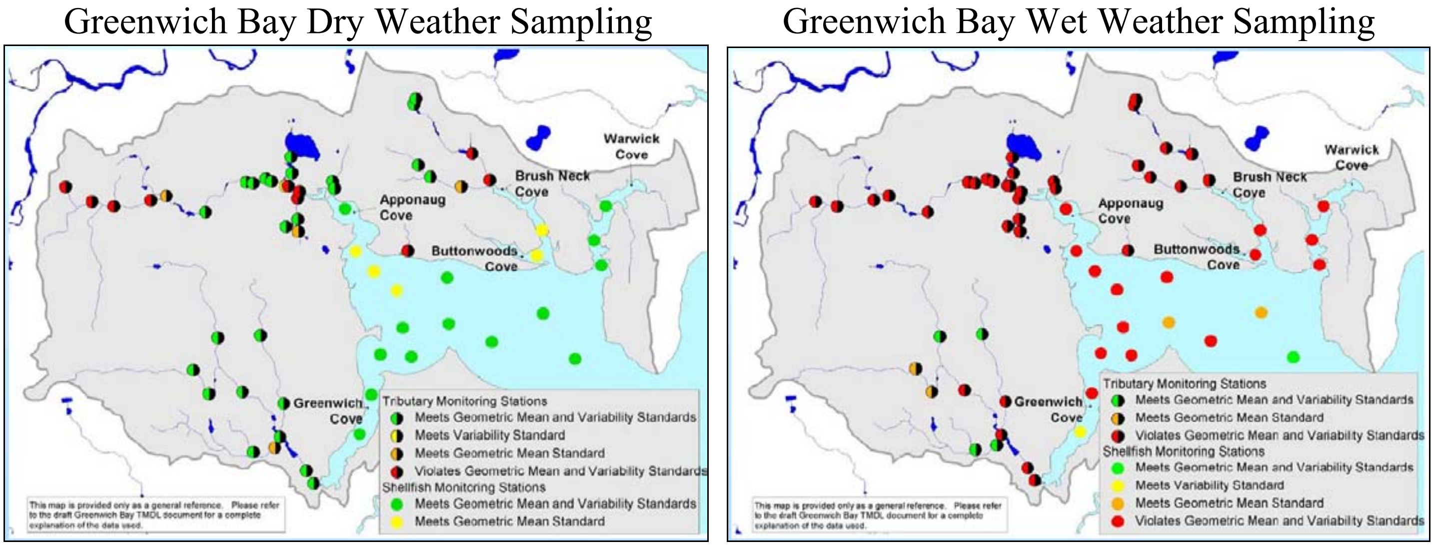

Greenwich Bay Dry Weather Sampling
Greenwich Bay Wet Weather Sampling

Figure 7: Summary of water quality sampling in Greenwich Bay, Rhode Island (RIDEM 2004b). See Greenwich Bay TMDL analysis (RIDEM 2004a) for explanation of data sources and sampling results.

Evaluations of California's coastal waters have revealed significant microbial contamination associated with the state's intense coastal development. Studies by Ackerman and Weisberg (2003), Bay *et al*. (2003, 1999), Dwight *et al*. (2002), Jiang *et al*. (2001) Noble *et al*. (2003c, 2000a, 2000b), Schiff *et al*. (2003), Schiff and Kinney (2001), and others have documented widespread contamination of the nearshore environment correlated with rainfall, river flows, and stormwater discharges. More specific to shellfish, Pitman (1995) evaluated the impact of two marine sewage outfalls on shellfish beds located midway between the coastal California communities of Goleta and Santa Barbara, and concluded that the treated discharges from the two outfalls did not adversely affect the shellfish growing areas. However, surface runoff and creek discharges from the watersheds between the two outfalls (about 8.5 miles apart) did correlate with high bacterial levels in the shellfish growing areas. The study documented high bacterial levels in the discharges during storm events and concluded that the mass loadings from the creeks during one rainy day exceeded the annual, disinfected loadings from the two sewage treatment plants. The study did not characterize the watershed pollution sources or correlate the bacterial loadings with different land uses.

And in a study of Whangateau Harbor in northeast New Zealand, De Luca-Abbott *et al*. (2000) correlated high winter rainfall with increased bacterial levels in stormwater discharges and contamination of the harbor, determining that "the effect of rainfall events on water, sediment, and shellfish bacterial levels unequivocally indicated that rainfall is associated with increased levels of enterococci" (p. 427). Cumulative loadings from the many stormwater outfalls, on-site sewage systems, and other nonpoint sources in the watershed led the authors to suggest that worst-case conditions for the harbor, in terms of human health risks, would involve wet-weather conditions during the summer tourist season when population and wastewater loadings are at their highest. The researchers also concluded that "the identification of ecological impacts in harbors and estuaries is problematic due to natural temporal and spatial variability” and a “better approach may be to focus on stormwater treatment rather than identification of effects” (p. 428).

CONCLUSIONS

Evaluation of the studies examining the effects of growth and development on microbial contamination of coastal waters reveals many strong correlations and other general observations that help explain the influential role that humans play in coastal ecosystems. The findings have broad application, but they must also be interpreted and applied to fit the unique site characteristics that exist in all settings. Analysis of the available scientific literature points to the following conclusions:

- Coastal areas are highly productive and sensitive environments. They are also highly valued places to live, work, and play. Two dramatic and related trends—population growth and urbanization—are stressing and degrading coastal ecosystems.
- Bivalve molluscan shellfish are effective carriers of enteric viruses and other pathogens. Actions that prevent and control fecal pollution in coastal areas where shellfish are grown and harvested are vital for safeguarding public health and environmental quality.
- Urbanization is perhaps the most significant of all land use changes, dramatically altering the natural capacity of watersheds to absorb and attenuate flows and contaminants. The imprint of urbanization is generally permanent and many of the related environmental impacts, including the contamination of shellfish growing areas, are difficult to mitigate or reverse.
- Microbial contamination is chronic and pervasive in many coastal areas of the United States and is closely correlated with population densities, development levels, rainfall events, stormwater runoff, and river flows.
- Research documenting the effects of human development on the health of stream systems is extensive and compelling. The available research examining the effects of development on the health of estuarine systems is more limited, but reveals strong and similar correlations.
- Impervious cover is the most widely researched landscape indicator for gauging the effects of development on aquatic ecosystems. Studies indicate that moderate levels of development in the range of 10 to 25 percent impervious cover degrade aquatic habitats of all kinds, including shellfish growing areas, and the degradation increases as development intensifies.
- Watershed hydrology has a significant effect on water quality. Shellfish growing areas can be degraded at low levels of development if there are raw fecal discharges or if hydrologic processes are disrupted and there is high connectivity between the pollution sources and nearshore waters. Actions that protect natural hydrologic functions and that reduce connectivity can help mitigate development impacts.
- Stormwater runoff is a defining characteristic of urbanizing landscapes that results from the conversion of natural land cover to impervious cover. Microbial concentrations in stormwater are generally high, due in part to significant fecal loadings from pets, other domestic animals, and wildlife.
- The available research supports long-standing observations that concentrated urban development is incompatible with safe, sustainable shellfish harvesting. However, there is no simple formula or rule, no single indicator or threshold, for determining the limits of growth in all shellfish watersheds.
- Pollution impacts can be prevented and mitigated using a variety of approaches and techniques, but there are practical limits to our ability and willingness to preserve coastal habitats and resources as development progresses. There is no replacement for sound land use planning and personal stewardship that recognize and preserve the inherent qualities of natural systems for buffering impacts and preserving clean water and healthy aquatic habitats.

Many factors affect the suitability of shoreline areas for growing and harvesting shellfish, and none is more vital than clean water. Coastal urbanization may be proceeding rapidly in some parts of the world, but the contamination and closure of shellfish growing areas is not inevitable. Better understanding of the tradeoffs and consequences associated with development should lead to improved decision-making with land use plans, pollution control programs, and other measures that play a central role in shellfish protection. Still more research is needed to better understand the relationship between development and microbial contamination in coastal areas, but the current state of knowledge points to a number of important actions that can be undertaken now to preserve the coastal environment for shellfish harvesting and other valued uses.

REFERENCES

Ackerman, D. and S. B. Weisberg. 2003. Relationship Between Rainfall and Beach Bacterial Concentrations on Santa Monica Bay Beaches. *Journal of Water and Health*. 1(2):85-89. (available at ftp://ftp.sccwrp.org/pub/download/PDFs/404_rain_study.pdf)

Alberti, M., D. Booth, K. Hill, B. Coburn, C. Avolio, S. Coe and D. Spirandelli. In press. The Impact of Urban Patterns on Aquatic Ecosystems: An Empirical Analysis in Puget Lowland Sub-basins. *Landscape Ecology*.

Arnold, C. L. and Gibbons, C. J. 1996. Impervious Surface Coverage: The Emergence of a Key Environmental Indicator. *Journal of the American Planning Association*. 62(2):243-258.

Bay, S., B. H. Jones, K. Schiff and L. Washburn. 2003. Water Quality Impacts of Stormwater Discharges to Santa Monica Bay. *Marine Environmental Research*. 56(1-2):205-223.

Bay, S, B. H. Jones and K. Schiff. 1999. *Study of the Impact of Stormwater Discharge on Santa Monica Bay*. Executive Summary. Prepared for the Los Angeles County Department of Public Works. Alhambra, California. 16 pp. (available at ftp://ftp.sccwrp.org/pub/download/PDFs/summseagrant.pdf)

Beach, D. 2002. *Coastal Sprawl: The Effects of Urban Design on Aquatic Ecosystems in the United States*. Pew Oceans Commission. Arlington, Virginia. 32 pp. (available at http://www.pewoceans.org/reports/water_pollution_sprawl.pdf)

Bennett, R., J. Knight, T. Sasaki, J. Johnson and G. Chang. 2000. Seasonal and Spatial Distribution of Coliform Bacteria and E. coli in a Rural California Estuary. In: *Fourth State of the Tomales Bay Conference*. October 6-7, 2000. Pt. Reyes Station, California. pp. 18-29. (available at http://ucce.ucdavis.edu/files/filelibrary/1410/1384.doc)

Bingham, D. R., F. X. Dougherty and S. F. Macfarlane. 1996. Successful Restoration of Shellfish Habitat by Control of Watershed Pollution Sources. In: *Watershed '96 Proceedings*. June 8-12, 1996. Baltimore, Maryland. pp. 908-910. (available at http://www.epa.gov/owow/watershed/Proceed/bingham.htm)

Boehm, A. B., S. B. Grant, J. H. Kim, S. L. Mowbray, C. D. McGee, C. D. Clark, D. M. Foley and D. E. Wellman. 2002. Decadal and Shorter Period Variability of Surf Zone Water Quality at Huntington Beach, California. *Environmental Science and Technology.* 36(18):3885-3892. (available at http://www.stanford.edu/~aboehm/estdecadel.pdf)

Bolstad, P. V. and W. T. Swank. 1997. Cumulative Impacts of Landuse on Water Quality in a Southern Appalachian Watershed. *Journal of the American Water Resources Association*. 33(3): 519-533. (available at http://www.srs.fs.usda.gov/pubs/rpc/1998-06/rpc_98jun_06.pdf)

Booth, D. B. 2000. *Forest Cover, Impervious-Surface Area, and the Mitigation of Urbanization Impacts in King County, Washington*. Prepared for King County Water and Land Resources Division. Seattle, Washington. 18 pp. (available at http://depts.washington.edu/cuwrm/research/forest.pdf)

Booth, D. B. 1991. Urbanization and the Natural Drainage System – Impacts, Solutions, and Prognoses. *The Northwest Environmental Journal*. 7(1):93-118. (available at http://depts.washington.edu/cuwrm/publictn/nwej1991.pdf)

Booth, D. B., D. Hartley and R. Jackson. 2002. Forest Cover, Impervious-Surface Area, and the Mitigation of Stormwater Impacts. *Journal of the American Water Resources Association*. 38(3):835-845.

Booth, D. B, J. R. Karr, S. Schauman, C. P. Konrad, S. A. Morley, M. G. Larson, P. C. Henshaw, E. J. Nelson and S. J. Burges. 2001. *Urban Stream Rehabilitation in the Pacific Northwest: Physical, Biological and Social Considerations*. Final Report, EPA Grant Number R82-5284-010. University of Washington. Seattle, Washington. 78 pp. (available at http://depts.washington.edu/cuwrm/research/final%20rehab%20report.pdf)

Booth, D. B. and C. R. Jackson. 1997. Urbanization of Aquatic Systems: Degradation Thresholds, Stormwater Detention and the Limits of Mitigation. *Journal of the American Water Resources Association*. 33(5):1077-1090. (available at http://courses.washington.edu/urbdp498/boothwrb.pdf)

Bosch. A. 1998. Human Enteric Viruses in the Water Environment: A Minireview. *International Microbiology*. 1(3):191-196. (available at http://www.im.microbios.org/03setember98/04%20Bosch.pdf)

British Columbia Stats. 2002. *British Columbia Regional District P.E.O.P.L.E Projection Run 26*. BC Stats, British Columbia Ministry of Management Services. Victoria, British Columbia. 1 p.

Bowen J. L. and I. Valiela. 2001. The Ecological Effects of Urbanization of Coastal Watersheds: Historical Increases in Nitrogen Loads and Eutrophication of Waquoit Bay Estuaries. *Canadian Journal of Fisheries and Aquatic Sciences*. 58(8):1489-1500.

Brown, K. 2000. Housing Density and Urban Land Use as Indicators of Stream Quality. In: *The Practice of Watershed Protection*. T. R. Schueler and H. K. Holland, eds. Center for Watershed Protection. Ellicott City, Maryland. pp. 123-127.

Breitburg, D. L., T. E. Jordan and D. Lipton. 2003. Preface—From Ecology to Economics: Tracing Human Influence in the Patuxent River Estuary and its Watershed. *Estuaries*. 26(2a):167-170.

Bunn, S. E. and A. H. Arthington. 2002. Basic Principles and Ecological Consequences of Altered Flow Regimes For Aquatic Biodiversity. *Environmental Management*. 30(4):492-507. (available at http://zooserv1.uni-muenster.de/limnology/seminars.old/ref_2.pdf)

Burton, G. A. and R. E. Pitt. 2002. *Stormwater Effects Handbook: A Toolbox for Watershed Managers Scientists, and Engineers*. CRC Press, Inc. Boca Raton, Florida. 928 pp. (available at http://www.epa.gov/ednnrmrl/publish/book/handbook/index.htm)

California Regional Water Quality Control Board. 2004. *Pathogens in Tomales Bay: Total Maximum Daily Load Final Project Report*. California Environmental Protection Agency, San Francisco Bay Regional Water Quality Control Board. Oakland, California. 102 pp. (available at http://www.swrcb.ca.gov/rwqcb2/TMDL/Tomales%20Bay%20Pathogens/final_proj_rpt_tomales_bay_pathogen_tmdl.pdf)

Castonguay, W. 1998. Stormwater Pollution Solutions in Ipswich. *Coastal Monitor*. Eight Towns and the Bay Committee, Massachusetts Bays Program. Merrimack Valley Planning Commission. Haverhill, Massachusetts. (available at http://www.naturecompass.org/8tb/news/9802_storm.html)

Center for Watershed Protection. 2004. *An Integrated Framework to Restore Small Urban Watersheds*. Manual No. 1 in Urban Subwatershed Restoration Manual Series. Center for Watershed Protection. Ellicott City, Maryland. 76 pp.

Center for Watershed Protection. 2003. *Impacts of Impervious Cover on Aquatic Systems*. Watershed Protection Research Monograph No. 1. Center for Watershed Protection. Ellicott City, Maryland. 142 pp.

Chestnut, D. E., G. I. Scott, B. C. Thompson, L. W. Webster, A. K. Leight, E. F. Wirth and M. H. Fulton. 2000. Chapter 3 Water Quality. In: *A Baseline Assessment of Environmental and Biological Conditions in Broad Creek and the Okatee River, Beaufort County, South Carolina*. Van Dolah, R. F, D. E. Chestnut and G. I. Scott, eds. Prepared by South Carolina Department of Health and Environmental Control, South Carolina Department of Natural Resources, and National Oceanic and Atmospheric Administration, National Ocean Service. Final Report to the Beaufort County Council. Beaufort County, South Carolina. pp. 18-64. (available at http://www.scdhec.gov/eqc/water/html/broadokateerp/ch3.pdf)

Cohen, J. E., C. Small, A. Mellinger, J. Gallup and J. Sachs. 1997. Estimates of Coastal Populations. *Science*. 278(5341):1211-1212.

Corbett, C. W., M. Wahl, D. E. Porter, D. Edwards and C. Moise. 1997. Nonpoint Source Runoff Modeling: A Comparison of a Forested Watershed and an Urban Watershed on the South Carolina Coast. *Journal of Experimental Marine Biology and Ecology*. 213:133-149.

Dadswell, J. V. 1993. Microbiological Quality of Coastal Waters and its Health Effects. *International Journal of Environmental Health Research*. 3:32-46.

Dale, V. H., S. Brown, R. A. Haeuber, N. T. Hobbs, N. Huntly, R. J. Naiman, W. E. Riebsame, M. G. Turner and T. J. Valone. Ecological Principles and Guidelines for Managing the Use of Land. *Ecological Applications*. 10(3):639-670. (available at http://www.fish.washington.edu/people/naiman/CV/reprints/dale_et_al_2000_ecoapp.pdf)

Dame, R., M. Alber, D. Allen, M. Mallin, C. Montague, A. Lewitus, A. Chalmers, R. Gardner, C. Gilman, B. Kjerfve, J. Pinckey and N. Smith. 2000. Estuaries of the South Atlantic Coast of North America: Their Geographical Signatures. *Estuaries*. 23(6):793-819.

De Luca-Abbott, S., G. D. Lewis and R. G. Creese. 2000. Temporal and Spatial Distribution of Enterococcus in Sediment, Shellfish Tissue, and Water in a New Zealand Harbour. *Journal of Shellfish Research*. 19(1):423-429.

Dojiri, M., M. Yamaguchi, S.B. Weisberg and H. J. Lee. 2003. Changing Anthropogenic Influence on the Santa Monica Bay Watershed. *Marine Environmental Research*. 56(1-2):1-14.

Duda, A. M. and K. D. Cromartie. 1982. Coastal Pollution from Septic Tank Drainfields. *Journal of the Environmental Engineering Division, American Society of Civil Engineers*. 108(6):1265-1279.

Dwight, R. H., J. C. Semenza, D. B. Baker and B. H. Olson. 2002. Association of Urban Runoff with Coastal Water Quality in Orange County, California. *Water Environment Research*. 74(1):82-90.

Eisele, W., B. J. Zimmer and R. Connell. 2001. Pressures on New Jersey Shellfish Waters. *Journal of Shellfish Research*. 20(3):1301-1304.

Elvidge, C. D., C. Milesi, J. B. Dietz, B. T. Tuttle, P. C. Sutton, R. Nemani and J. E. Vogelmann. 2004. U.S. Constructed Area Approaches the Size of Ohio. *Eos*. 85(24):233.

Emmett, R., R Llansó, J. Newton, R. Thom, M. Hornberger, C. Morgan, C. Levings, A. Copping and P. Fishman. 2000. Geographical Signatures of North American West Coast Estuaries. *Estuaries*. 23(6):765-792.

Faigenblum, J., G. Plews and J. Armstrong. 1988. Chemicals and Biological Organisms in Puget Sound Recreational Shellfish. In: *Proceedings, First Annual Meeting on Puget Sound Research*. Puget Sound Water Quality Authority. Seattle, Washington. pp. 307-318.

Funders' Network for Smart Growth and Livable Communities. 2004. *Water and Smart Growth: The Impacts of Sprawl on Aquatic Systems*. Translation Paper No. 14. Funders' Network for Smart Growth and Livable Communities. Coral Gables, Florida. 18 pp. (available at http://www.fundersnetwork.org/usr_doc/Water_and_Smart_Growth_Final.pdf)

Geldreich, E. 1978. Bacterial Populations and Indicator Concepts in Feces, Sewage, Stormwater and Solid Wastes. In: *Indicators of Viruses in Water and Food*. G. Berg, ed. Ann Arbor Science Publication, Inc. Ann Arbor, Michigan. pp. 51-97.

Georgia Basin Ecosystem Initiative. 2002. *Georgia Basin-Puget Sound Ecosystem Indicators Report*. A Report of the Transboundary Georgia Basin-Puget Sound Environmental Indicators Working Group. Georgia Basin Ecosystem Initiative Publication Number EC/GB-01-034. Washington State Department of Ecology Publication Number 02-01-002. Olympia, Washington. 22 pp. (available at http://wlapwww.gov.bc.ca/cppl/gbpsei/documents/gbpsei.pdf)

Gergel, S. E., M. G. Turner, J. R. Miller, J. M. Melack and E. H. Stanley. 2002. Landscape Indicators of Human Impacts to Riverine Systems. *Aquatic Sciences*. 64(2):118-128. (available at http://www.birkhauser.ch/journals/2700/papers/2064002/20640118.pdf)

Goyal, S. M., W. N. Adams, M. L. O'Malley and D. W. Lear. 1984. Human Pathogenic Viruses at Sewage Sludge Disposal Sites in the Middle Atlantic Region. *Applied and Environmental Microbiology*. 48(4):758-763. (available at http://www.pubmedcentral.nih.gov/picrender.fcgi?artid=241609&action=stream&blobtype=pdf)

Griffin, D. W., K. A. Donaldson, J. H. Paul and J. B. Rose. 2003. Pathogenic Human Viruses in Coastal Waters. *Clinical Microbiology Reviews*. 16(1):129-143. (available at http://cmr.asm.org/cgi/reprint/16/1/129.pdf)

Griffin, D. W., C. J. Gibson III, E. K. Lipp, K. Riley, J. H. Paul III and J. B. Rose. 1999. Detection of Viral Pathogens by Reverse Transcriptase PCR and of Microbial Indicators by Standard Methods in the Canals of the Florida Keys. *Applied and Environmental Microbiology*. 65(9):4118-4125. (available at http://aem.asm.org/cgi/reprint/65/9/4118.pdf)

Haile, R. W., J. S. Witte, M. Gold, R. Cressey, C. McGee, R. C. Millikan, A. Glasse, N. Harawa, C. Ervin, P. Harmon, J. Harper, J. Dermand, J. Alamillo, K. Barrett, M. Nides and G. Wang. 1999. The Health Effects of Swimming in Ocean Water Contaminated by Storm Drain Runoff. *Epidemiology*. 10(4):355-63.

Henrickson, S. E., T. Wong, P. Allen, T. Ford and P. R. Epstein. 2001. Marine Swimming-Related Illness: Implications for Monitoring and Environmental Policy. *Environmental Health Perspectives*. 109(7):645-650. (available at http://ehp.niehs.nih.gov/members/2001/109p645-650henrickson/henrickson.pdf)

Hernroth, B. E., A. Conden-Hansson, A. Rehnstam-Holm, R. Girones and A. K. Allard. 2002. Environmental Factors Influencing Human Viral Pathogens and Their Potential Indicator Organisms in the Blue Mussel, *Mytilus edulis*: the First Scandinavian Report. *Applied and Environmental Microbiology*. 68(9):4523-4533.

Hinrichson, D. 1999. The Coastal Population Explosion. In: *Workshop Proceedings: Trends and Future Challenges for U.S. National Ocean and Coastal Policy*. B. Cicin-Sain, R. W. Knecht and N. Foster, eds. January 22, 1999. Washington. D.C. National Ocean Service, National Oceanic and Atmospheric Administration. pp 27-29. (available at http://www.oceanservice.noaa.gov/websites/retiredsites/natdia_pdf/ctrends_proceed.pdf)

Holland, A. F. 2000. Coastal Sentinels. *South Carolina Wildlife*. 47:36-40. (available at http://www.dnr.state.sc.us/magazine/magazinend00/html/sentinelnd00.htm)

Holland, A. F., D. M. Sanger, C. P. Gawle, S. B. Lerberg, M. S. Santiago, G. H. M. Riekerk, L. E. Zimmerman and G. I. Scott. 2004. Linkages Between Tidal Creek Ecosystems and the Landscape and Demographic Attributes of their Watersheds. *Journal of Experimental Marine Biology and Ecology*. 298(2):151-178.

Holland, A. F and D. M. Sanger. 2001. Validation of the Effects of Watershed Development on Tidal Creek Systems. In: *EMAP Symposium 2001: Coastal Monitoring through Partnerships*. April 24-27, 2001. Pensacola Beach, Florida. p. 107. (available at http://www.epa.gov/emap/html/pubs/docs/otherdocs/symposia/montpart.pdf)

Holland, A. F., G. H. Riekerk, S. B. Lerberg, L. E. Zimmerman and D. M. Sanger. 1998. Assessment of the Impact of Watershed Development on the Nursery Functions of Tidal Creek Habitats. In: *Workshop Proceedings: Biological Habitat Quality Indicators for Essential Fish Habitat*, July 14-15, 1997. Charleston, South Carolina. S. Ian Hartwell, ed. NOAA Technical Memorandum NMFS-F/SPO-32. pp. 48-52. (available at http://www.nmfs.noaa.gov/habitat/ecosystem/habitatdocs/efhwkshpdoc.PDF)

Hopkinson, C. S. and J. J. Vallino. 1995. The Relationships Among Man’s Activities in Watersheds and Estuaries: Effects on Patterns of Estuarine Community Metabolism. *Estuaries*. 18(4):598-621. (available at http://estuaries.olemiss.edu/cdrom/ESTU1995_18_4_598_621.pdf)

Hunsaker, C. T. and D. A. Levine. 1995. Hierarchical Approaches to the Study of Water Quality in Rivers. *BioScience*. 45(3): 193-203.

Hydroqual, Inc. 1996. *Design Criteria Report: Kensico Watershed Stormwater Best Management Facilities*. Appendix C. Report Prepared for City of New York, Department of Environmental Protection. 240 pp. Referenced in: Schueler, T. R. 2000. Microbes and Urban Watersheds: Concentrations, Sources, and Pathways. In: *The Practice of Watershed Protection*. T. R. Schueler and H. K. Holland, eds. Center for Watershed Protection. Ellicott City, Maryland. pp. 74-84.

Hynes, H. B. 1975. The Stream and its Valley. *Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie*. 19:1-15.

Jiang, S., R. Noble and W. Chu. 2001. Human Adenoviruses and Coliphages in Urban Runoff-Impacted Coastal Waters of Southern California. *Applied and Environmental Microbiology*. 67(1):179-184. (available at http://aem.asm.org/cgi/reprint/67/1/179.pdf)

Johnson, L. B. and S. H. Gage. 1997. Landscape Approaches to the Analysis of Aquatic Ecosystems. *Freshwater Biology*. 37:113-132.

Joubert, L. and J. Lucht. 2000. *Wickford Harbor Watershed Assessment*. Department of Natural Resources Science, University of Rhode Island Cooperative Extension. Kingston, Rhode Island. 63 pp. (available at http://www.uri.edu/ce/wq/mtp/wick/report.html)

Karr, J. R. 1998. Rivers as Sentinels: Using the Biology of Rivers to Guide Landscape Management. In: *River Ecology and Management Lessons from the Pacific Coast Ecoregion*. R. J. Naiman and R. B. Bilby, eds. Springer-Verlag. New York, New York. pp. 502-528. (available at http://www.cbr.washington.edu/salmonweb/pubs/pacnwfin.pdf)

Kelsey, H., D. E. Porter, G. Scott, M. Neet and D. White. 2004. Using Geographic Information Systems and Regression Analysis to Evaluate Relationships Between Land Use and Fecal Coliform Bacterial Pollution. *Journal of Experimental Marine Biology and Ecology*. 298(2):197-209.

Kelsey, H., G. Scott, D. E. Porter, B. Thompson and L. Webster. 2003. Using Multiple Antibiotic Resistance and Land Use Characteristics to Determine Sources of Fecal Coliform Bacterial Pollution. *Environmental Monitoring and Assessment*. 81(1-3):337-348.

Klein, R. D. 1979. Urbanization and Stream Quality Impairment. *Water Resources Bulletin*. 15(4):948-963.

Konrad, C. P. and D. B. Booth. 2002. *Hydrologic Trends Associated with Urban Development for Selected Streams in the Puget Sound Basin, Western Washington*. U. S. Geological Survey Water Resources Investigations Report 02-4040. U.S. Geological Survey, U.S. Department of the Interior. Tacoma, Washington. 40 pp. (available at http://water.usgs.gov/pubs/wri/wri024040/pdf/WRIR02-4040.pdf)

Konrad, C. P. and D. B. Booth. 2001. Hydrologic Trends and Hydrologic Monitoring in Urbanizing Streams of Western Washington. *The Washington Water Resource*. Center for Urban Water Resources Management, University of Washington. Seattle, Washington. 12(4):4-11. (available at http://depts.washington.edu/cwws/Outreach/Publications/CUWRM%20newsletter/fall01.pdf)

Krahforst, C., S. McKenna, D. Sargeant and R. Knowles. 2002. *An Evaluation of Innovative Stormwater Treatment Installations Designed to Mitigate Storm Drain Pollution Impacting Shellfish Beds at Wychmere Harbor, Harwich and the Jones River, Gloucester, Massachusetts*. Section 319 NPS Project #95-02. Prepared for Massachusetts Department of Environmental Protection and U.S. Environmental Protection Agency Region 1. 30 pp. (available at http://www.state.ma.us/czm/masection319npsproject9502.pdf)

Leecaster, M. K. and S. B. Weisberg. 2001. Effect of Sampling Frequency on Shoreline Microbiology Assessments. *Marine Pollution Bulletin*. 42:1150-1154.

Lees, D. 2000. Viruses and Bivalve Shellfish. *International Journal of Food Microbiology*. 59:81-116.

Leopold, L. B. 1968. *Hydrology for Urban Land Planning—A Guidebook on the Hydrologic Effects of Urban Land Use*. U.S. Geological Survey Circular 554. Washington, D.C. 18 pp.

Lerberg, S. B., A. F. Holland and D. M. Sanger. 2000. Responses to Tidal Creek Macrobenthic Communities to the Effects of Watershed Development. *Estuaries*. 23(6):838-853.

Lilja, J. and S. Glasoe. 1993. Uses and Limitations of Coliform Indicators in Shellfish Sanitation Programs. *Puget Sound Notes*. Puget Sound Water Quality Authority. Olympia, Washington.30:4-6.

Lipp, E. K., J. L. Jarrell, D. W. Griffin, J. Lukasik, J. Jacukiewicz and J. B. Rose. 2002. Preliminary Evidence for Human Fecal Contamination in Corals of the Florida Keys, USA. *Marine Pollution Bulletin*. 44:666-670. (available at http://www.icriforum.org/docs/coralmucus.pdf)

Lipp, E. K., S. A. Farrah and J. B. Rose. 2001a. Assessment and Impact of Microbial Fecal Pollution and Human Enteric Pathogens in a Coastal Community. *Marine Pollution Bulletin*. 42(4):286-293.

Lipp, E. K., R. Kurz, R. Vincent, C. Rodriquez-Palacios, S. R. Farrah and J. B. Rose. 2001b. The Effects of Seasonal Variability and Weather on Fecal Pollution and Enteric Pathogens in a Subtropical Estuary. *Estuaries*. 24(2): 266-276.

Lipp, E. K. and J. B. Rose. 2001. Microbial Fecal Pollution in Tidal Creeks and Canals in Developed Regions of Southwest Florida. In: Estuarine Research Federation Conference Abstract, 16th Biennial Conference. November 4-8, 2001. St. Pete Beach, Florida. 1 p. (available at http://erf.org/user-cgi/conference_abstract.pl?conference=erf2001&id=518)

Lipp, E. K. and J. B. Rose. 1997. The Role of Seafood in Foodborne Diseases in the United States of America. *Review of Scientific Techniques, Office International des Epizooties Review*. 16(2):620-40.

Macfarlane, S. L. 1997. Shellfish Habitat Mitigation through Stormwater Control: Local Effort and Reward. In: Abstracts of Technical Papers Presented at the First Meeting of the International Conference on Shellfish Restoration, Hilton Head Island, South Carolina, November 20-23, 1996. *Journal of Shellfish Research*. 16(1):271.

Macfarlane, S. L. 1996. Shellfish as the Impetus for Embayment Management. *Estuaries*. 19(2A): 311-319. (available at http://estuaries.olemiss.edu/cdrom/ESTU1996_19_2A_311_319.pdf)

Macfarlane, S. L. 1988. Shellfish Resource Degradation as a Function of Land Use Practices. In: Abstracts of Technical Papers Presented at the 1988 Annual Meeting National Shellfisheries Association, New Orleans, Louisiana, June 26-30, 1988. *Journal of Shellfish Research*. 7(1):198.

Maiolo, J. and P. Tschetter. 1981. Relating Population Growth to Shellfish Bed Closures: A Case Study from North Carolina. *Coastal Zone Management Journal*. 9(1):1-18.

Mallin, M. A. and A. J. Lewitus. 2004. The Importance of Tidal Creek Ecosystems. *Journal of Experimental Marine Biology and Ecology*. 298(2):145-149.

Mallin, M. A., S. H. Ensign, M. R. McIver, G. C. Shank and P. K. Fowler. 2001. Demographic, Landscape, and Meteorological Factors Controlling the Microbial Pollution of Coastal Waters. *Hydrobiologia*. 460:185-193.

Mallin, M. A., K. E. Williams, E. C. Esham and R. P. Lowe. 2000a. Effect of Human Development on Bacteriological Water Quality in Coastal Watersheds. *Ecological Applications*. 10(4):1047-1056.

Mallin, M. A., J. M. Burkholder, L. B. Cahoon and M. H. Posey. 2000b. North and South Carolina Coasts. *Marine Pollution Bulletin*. 41(1-6):56-75. (available at http://www.ncsu.edu/wq/webfiles/publications/2000northandsouth.pdf)

Marchman, G. L. 2000. *An Analysis of Stormwater Inputs to the Apalachicola Bay*. Northwest Florida Water Management District Water Resources Special Report 00-01. Northwest Florida Water Management District. Havana, Florida. 63 pp. (available at http://www.state.fl.us/nwfwmd/pubs/apal_stormwater_inputs/apalachicola_stormwater_inputs.htm)

Massachusetts Department of Environmental Protection. 2002. *Total Maximum Daily Loads of Bacteria for Little Harbor*. Division of Watershed Management, Massachusetts Department of Environmental Protection. Worcester, Massachusetts. 44 pp. (available at http://www.mass.gov/dep/brp/wm/files/litlharb.pdf)

May, C.W., R. R. Horner, J. R. Karr, B. W. Mar and E. B. Welch. 2000. Effects of Urbanization on Small Streams in the Puget Sound Ecoregion. In: *The Practice of Watershed Protection*. T. R. Schueler and H. K. Holland, eds. Center for Watershed Protection. Ellicott City, Maryland. pp. 87-98.

McBride, M. 2001. Spatial Effects of Urbanization on Physical Conditions in Puget Sound Lowland Streams. *The Washington Water Resource*. 12(2):1-10. (available at http://depts.washington.edu/cwws/Outreach/Publications/CUWRM%20newsletter/summer01.pdf)

Mississippi Department of Environmental Quality. 2002. *Fecal Coliform TMDL for the Back Bay of Biloxi and Biloxi Bay: Coastal Streams Basin, Harrison and Jackson Counties, Mississippi*. Mississippi Department of Environmental Quality. Jackson, Mississippi. 91 pp. (available at http://www.deq.state.ms.us/MDEQ.nsf/pdf/WQAB_BackBayJn02/$File/CoastalSBBackBay&BiloxiBayJn02.pdf?OpenElement)

Morse, C. C., A. D. Huryn and C. Cronan. 2003. Impervious Surface Area as a Predictor or the Effects of Urbanization on Stream Insect Communities in Maine, U.S.A. *Environmental Monitoring and Assessment*. 89(1):95-127. (available at http://ipsapp008.kluweronline.com/content/getfile/4674/124/2/fulltext.pdf)

Naiman, R. J., T. J. Beechie, L. E. Benda, D. R. Berg, P. A. Bison, L. H. MacDonald, M. D. O'Connor, P. L. Olson and E. A. Steel. 1992. Fundamental Elements of Ecologically Healthy Watersheds in the Pacific Northwest Coastal Ecoregion. In: *Watershed Management: Balancing Sustainability with Environmental Change*. R. J. Naiman, ed. Springer-Verlag. New York, New York. pp. 127-188. (available at http://www.fish.washington.edu/people/naiman/CV/reprints/naiman_fundamental_1992.pdf)

National Research Council. 2004. *Indicators for Waterborne Pathogens*. Committee on Indicators for Waterborne Pathogens, National Research Council. National Academy Press. Washington, D.C. 236 pp. (available at http://www.nap.edu/books/0309091225/html/)

National Research Council. 1999. *From Monsoons to Microbes: Understanding the Ocean's Role in Human Health*. Committee on the Ocean's Role in Human Health, National Research Council. National Academy Press. Washington, D.C. 144 pp. (available at http://www.nap.edu/books/0309065690/html/)

National Research Council. 1994. *Priorities for Coastal Ecosystem Science*. Committee to Identify High-Priority Science to Meet National Coastal Needs, National Research Council. National Academy Press. Washington, D.C. 106 pp. (available at http://books.nap.edu/books/0309050960/html/index.html)

National Research Council. 1993. *Managing Wastewater in Coastal Urban Areas*. Committee on Wastewater Management for Coastal Urban Areas, National Research Council. National Academy Press. Washington, D.C. 496 pp. (available at http://www.nap.edu/books/0309048265/html/index.html)

National Research Council. 1991. *Seafood Safety*. Committee on Evaluation of the Safety of Fishery Products, Food and Nutrition Board, Institute of Medicine. National Academy Press. Washington, D.C. 452 pp. (available at http://www.nap.edu/books/0309043875/html/index.html)

National Oceanic and Atmospheric Administration. 1998a. Pressures on Coastal Environments—Population: Distribution, Density and Growth. In: *State of the Coast Report*. National Oceanic and Atmospheric Administration. Silver Spring, Maryland. 32 pp. (available at http://oceanservice.noaa.gov/websites/retiredsites/sotc_pdf/POP.PDF)

National Oceanic and Atmospheric Administration. 1998b. State of the Coastal Environment—Classified Shellfish Growing Waters. In: *State of the Coast Report*. National Oceanic and Atmospheric Administration. Silver Spring, Maryland. 33 pp. (available at http://oceanservice.noaa.gov/websites/retiredsites/sotc_pdf/SGW.PDF)

National Oceanic and Atmospheric Administration. 1997a. *The 1995 National Shellfish Register of Classified Growing Waters*. Office of Ocean Resources Conservation and Assessment, National Oceanic and Atmospheric Administration. Silver Spring, Maryland. 398 pp. (available at http://spo.nos.noaa.gov/projects/95register/)

National Oceanic and Atmospheric Administration. 1997b. *National Shellfish Register Nothing to Clam Up About*. NOAA News Release 97-063. 2 pp. (available at http://www.publicaffairs.noaa.gov/pr97/oct97/noaa97-063.html)

National Science and Technology Council. 1995. *Setting a New Course for U.S. Coastal Science*. National Science and Technology Council, Committee on Environment and Natural Resources, National Oceanic and Atmospheric Administration. Silver Spring, Maryland. 111 pp. (available at http://www.cop.noaa.gov/pubs/suscos/1-cont.html)

Nelson, E. J. and D. B. Booth. 2002. Sediment Sources in an Urbanizing, Mixed Land-Use Watershed. *Journal of Hydrology*. 264:51-68. (available at http://es.epa.gov/ncer_pubs/full_text/10377.pdf)

New York Department of Environmental Conservation. 2003. *Pathogen Total Maximum Daily Loads for Shellfish Waters in Oyster Bay Harbor and Mill Neck Creek, Nassau County, New York*. New York Department of Environmental Conservation. Albany, New York. 96 pp. (available at http://www.dec.state.ny.us/website/dow/oystbay.pdf)

Noble, R. T., D. F. Moore, M. K. Leecaster, C. D. McGee and S. B. Weisberg. 2003a. Comparison of Total Coliform, Fecal Coliform, and Enterococcus Bacterial Indicator Response for Ocean Recreational Water Quality Testing. *Water Research*. 37:1637-1643. (available at ftp://ftp.sccwrp.org/pub/download/PDFs/383_micro_indicator.pdf)

Noble, R. T., S. B. Weisberg, M. K. Leecaster, C. D. McGee, K. Ritter, K. O. Walker and P. M. Vainik. 2003b. Comparison of Beach Bacterial Water Quality Indicator Measurement Methods. *Environmental Monitoring and Assessment*. 81(1-3):301-312. (available at http://www.marine.unc.edu/pdf/noble/noblebeachwaterqualitycomparison.pdf)

Noble, R. T., S. B. Weisberg, M. K. Leecaster, C. D. McGee, J. H. Dorsey, P. Vainik and V. Orozco-Borbón. 2003c. Storm Effects on Regional Beach Water Quality Along the Southern California Shoreline. *Journal of Water and Health*. 1(1):23-31. (available at http://www.iwaponline.com/jwh/001/0023/0010023.pdf)

Noble, R. T. and J. A. Fuhrman. 2001. Enteroviruses Detected by Reverse Transcriptase Polymerase Chain Reaction from the Coastal Waters of Santa Monica Bay, California: Low Correlation to Bacterial Indicators. *Hydrobiologia*. 460(1-3):175-184.

Noble, R. T., J. H. Dorsey, M. Leecaster, V. Orozco-Borbón, D. Reid, K. Schiff and S. B. Weisberg. 2000a. A Regional Survey of the Microbiological Water Quality Along the Shoreline of the Southern California Bight. *Environmental Monitoring and Assessment*. 64:435-447. (available at http://www.marine.unc.edu/pdf/noble/NobleAssessmentarticle.pdf)

Noble, R. T., M. K. Leecaster, C. D. McGee, D. F. Moore, V. Orozco-Borbon, K. Schiff, P. M. Vainik and S. B. Weisberg. 2000b. *Storm Event Shoreline Microbiology: Southern California Bight 1998 Regional Monitoring Program Volume 3*. Southern California Coastal Water Research Project. Westminster, California. 63 pp. (available at ftp://ftp.sccwrp.org/pub/download/PDFs/stormevent2000.pdf)

North Carolina Coastal Federation. 2002. *2002 State of the Coast Report.* North Carolina Coastal Federation. Newport, North Carolina. 20 pp. (available at http://www.nccoast.org/Soc2002/soc02.htm)

Oregon Department of Environmental Quality. 2001. *Tillamook Bay Watershed Total Maximum Daily Load (TMDL)*. Oregon Department of Environmental Quality. Portland, Oregon. 80 pp. (available at http://www.deq.state.or.us/wq/tmdls/Tillamk/TillamookTMDLDoc.pdf)

Paul, R. W. 2001. Geographical Signatures of Middle Atlantic Estuaries: Historical Layers. *Estuaries*. 24(2):151-166.

Paul, M. J. and J. L. Meyer. 2001. Streams in the Urban Landscape. *Annual Review of Ecology and Systematics*. 32:333-365.

Pew Oceans Commission. 2003. *America's Living Oceans: Charting a Course for Sea Change*. Pew Oceans Commission. Arlington, Virginia. 127 pp. (available at http://www.pewoceans.org/oceans/downloads/oceans_report.pdf)

Pitman, R. W. 1995. Wastewater Bacteria and Shellfish. *Bulletin Southern California Academy of Sciences*. 94(1):92-102.

Pitt, R., A. Maestre, R. Morquecho, T. Brown, T. Schueler, K. Cappiella, P. Sturm and C. Swann. 2004. *Research Progress Report: Findings from the National Stormwater Quality Database*. Center for Watershed Protection. Ellicott City, Maryland. 10 pp. (available at http://www.cwp.org/NPDES_research_report.pdf)

Pitt, R. 2000a. Chapter Five, Receiving Water and Other Impacts. In: *Innovative Urban Wet-Weather Flow Management Systems*. J. P. Heaney, R. Pitt and R. Field. Publication No. EPA/600/R-99/029. National Risk Management Research Laboratory, U.S. Environmental Protection Agency. Cincinnati, Ohio. 443 pp. (available at http://www.epa.gov/ednnrmrl/publish/book/epa-600-r-99-029/)

Pitt, R. 2000b. Chapter Four, Source Characterization. In: *Innovative Urban Wet-Weather Flow Management Systems*. J. P. Heaney, R. Pitt and R. Field. Publication No. EPA/600/R-99/029. National Risk Management Research Laboratory, U.S. Environmental Protection Agency. Cincinnati, Ohio. 443 pp. (available at http://www.epa.gov/ednnrmrl/publish/book/epa-600-r-99-029/)

Poff, N. L, J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B.D. Richter, R. E Sparks and J. C. Stromberg. 1997. The Natural Flow Regime: A Paradigm for River Conservation and Restoration. *BioScience*. 47(11):769-784. (available at http://www.snre.umich.edu/riverflows/flow_regime/naturalflow.pdf)

Puget Sound Action Team. 2002a. *Puget Sound's Health 2002*. Puget Sound Action Team. Olympia, Washington. 16 pp. (available at http://www.psat.wa.gov/Publications/pshealth2002/pshealth.html)

Puget Sound Action Team. 2002b. *Puget Sound Update 2002: Eighth Report of the Puget Sound Ambient Monitoring Program*. Puget Sound Action Team. Olympia, Washington. 144 pp. (available at http://www.psat.wa.gov/Publications/update_02/update_02.htm)

Puget Sound Action Team. 2000. *Puget Sound Water Quality Management Plan.* Puget Sound Action Team. Olympia, Washington. 148 pp. (available at http://www.psat.wa.gov/Publications/manplan00/mp_index.htm)

Richards, G. P. 1987. Shellfish-Associated Enteric Virus Illness in the United States, 1934-1984. *Estuaries*. 10(1):84-85. (available at http://estuaries.olemiss.edu/cdrom/ESTU1987_10_1_84_85.pdf)

Rhode Island Department of Environmental Management. 2004a. *Draft Total Maximum Daily Load Analysis for Greenwich Bay Waters*. Office of Water Resources, Rhode Island Department of Environmental Management. Providence, Rhode Island. 45 pp. (available at http://www.state.ri.us/dem/programs/benviron/water/quality/rest/pdfs/gbtmdl.pdf)

Rhode Island Department of Environmental Management. 2004b. *Bacteria Total Maximum Daily Load Analysis for Greenwich Bay Waters*. PowerPoint Presentation. Office of Water Resources, Rhode Island Department of Environmental Management. Providence, Rhode Island. (available at http://www.state.ri.us/dem/programs/benviron/water/quality/rest/pdfs/gbpresen.pdf)

Roman, C. T., N. Jaworski, F. T. Short, S. Findlay and R. S. Warren. 2000. Estuaries of the Northeastern United States: Habitat and Land Use Signatures. *Estuaries*. 23(6):743-764.

Rose, J. B., J. H. Paul, M. R. McLaughlin, V. J. Harwood, S. Farrah, M. Tamplin, G. Lukasik, M. D. Flanery, P. Stanek, H. Greening and M. Hammond. 2001a. *Healthy Beaches Tampa Bay*. Tampa Bay Estuary Program Technical Report No. 03-01. Tampa Bay Estuary Program. St. Petersburg, Florida. 213 pp.

Rose, J. B, P. R. Epstein, E. K. Lipp, B. H. Sherman, S. M. Bernard and J. A. Patz. 2001b. Climate Variability and Change in the United States: Potential Impacts on Water- and Foodborne Diseases Caused by Microbiologic Agents. *Environmental Health Perspectives*. 109(2):211-220. (available at http://ehpnet1.niehs.nih.gov/docs/2001/suppl-2/211-221rose/rose.pdf)

Rose, J. B., R. M. Atlas, C. P. Gerba, M. J. R. Gilchrist, M. W. LeChevallier, M. D. Sobsey, M. V. Yates, G. H. Cassell and J. M. Tiedje. 1999. *Microbial Pollutants in our Nation's Water: Environmental and Public Health Issues*. American Society for Microbiology. Washington, D.C. 16 pp. (available at http://www.asm.org/ASM/files/CCPAGECONTENT/DOCFILENAME/0000005987/waterreport[1].pdf)

Roth, N. E., J. D. Allan and D. L. Erickson. 1996. Landscape Influences on Stream Biotic Integrity Assessed at Multiple Spatial Scales. *Landscape Ecology*. 11(41):141-156.

Sair, A. I., D. H. D'Souza and L. A. Jaykus. 2002. Human Enteric Viruses as Causes of Foodborne Disease. Comprehensive Reviews in Food Science and Food Safety. *Institute of Food Technologies*. 1(2):73-79. (available at http://www.ift.org/pdfs/crfsfs/crfsfsv01n2p073-089ms20010312.pdf)

Sanger, D. M., A. F. Holland and G. I. Scott. 1999a. Tidal Creek and Salt Marsh Sediments in South Carolina Coastal Estuaries: I. Distribution of Trace Metals. *Archive of Environmental Contamination and Toxicology*. 37:445-457.

Sanger, D. M., A. F. Holland and G. I. Scott. 1999b. Tidal Creek and Salt Marsh Sediments in South Carolina Coastal Estuaries: II. Distribution of Organic Contaminants. *Archive of Environmental Contamination and Toxicology*. 37:458-471.

Schiff, K. C., Morton, J. and S. B. Weisberg. 2003. Retrospective Evaluation of Shoreline Water Quality Along Santa Monica Bay Beaches. *Marine Environmental Research*. 56(1-2):245-253. (earlier version available at ftp://ftp.sccwrp.org/pub/download/PDFs/1999ANNUALREPORT/23_ar36.pdf)

Schiff, K. C. and P. Kinney. 2001. Tracking Sources of Bacterial Contamination in Stormwater Discharges from Mission Bay, California. *Water Environment Research*. 73:534-542. (earlier version available at ftp://ftp.sccwrp.org/pub/download/PDFs/1999ANNUALREPORT/07_ar06.pdf)

Schroeder, E. D., W. M. Stallard, D. E. Thompson, F. J. Loge, M. A. Deshussess and H. H. J. Cox. 2002. *Management of Pathogens Associated with Storm Drain Discharge: Results of Investigations of the Presence of Human Pathogens in Urban Storm Drains*. Report No. CTSW-RT-02-025 prepared for Division of Environmental Analysis, California Department of Transportation. Sacramento, California. 99 pp. (available at http://www.dot.ca.gov/hq/env/stormwater/special/recent_reports/stormdrain_pathogens_2002.pdf)

Schueler, T. R. 2000a. Why Stormwater Matters. In: *The Practice of Watershed Protection*. T. R. Schueler and H. K. Holland, eds. Center for Watershed Protection. Ellicott City, Maryland. pp. 365-370. (available at http://www.uppervalleyleague.org/Why%20Stormwater%20Matters.pdf)

Schueler, T. R. 2000b. The Importance of Imperviousness. In: *The Practice of Watershed Protection*. T. R. Schueler and H. K. Holland, eds. Center for Watershed Protection. Ellicott City, Maryland. pp. 7-18. (available at http://www.uppervalleyleague.org/storm2B.pdf)

Schueler, T. R. 2000c. Microbes and Urban Watersheds: Concentrations, Sources, and Pathways. In: *The Practice of Watershed Protection*. T. R. Schueler and H. K. Holland, eds. Center for Watershed Protection. Ellicott City, Maryland. pp. 74-84. (http://www.polytechnic.edu.na/Schools/civil/Libraries/Hydrology/17-Microbes%20in%20Urban%20Watersheds.pdf)

Schueler, T. R. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices*. Department of Environmental Programs, Metropolitan Washington Council of Governments. Washington, D.C. 275 pp. Referenced in: Center for Watershed Protection. 2003. *Impacts of Impervious Cover on Aquatic Systems*. Watershed Protection Research Monograph No. 1. Center for Watershed Protection. Ellicott City, Maryland. 142 pp.

Scott, G. I., L. Webster, B. Thompson, W. Ellenberg, P. Comar and G. P Richards. 1998. The Impacts of Urbanization on Shellfish Harvesting Waters: Development of Techniques to Identify Coliform Pollution Sources. In: Abstracts of Technical Papers Presented at the International Conference on Shellfish Restoration, Hilton Head Island, South Carolina, November 18-21, 1998. *Journal of Shellfish Research*. 17(4):1312-1313.

Scott, G. I., M. H. Fulton, E. D. Strozier, P. B. Key, J. W. Daugomah, D. Porter and S. Strozier. 1996. The Effects of Urbanization on the American Oyster, *Crassostrea virginica* (Gmelin*)*. In: Abstracts of Technical Papers Presented at the 88th Annual Meeting of the National Shellfisheries Association, April 14-18, 1996, Baltimore, Maryland. *Journal of Shellfish Research*. 15(2):523-524.

Small, C. and J. E. Cohen. 2004. Continental Physiography, Climate and the Global Distribution of Human Population. *Current Anthropology*. 45(2):269-276. (earlier version available at http://www.ldeo.columbia.edu/~small/PDF/ISDE_SmallCohen.pdf)

Smith, J. H., J. D. Wickham, D. Norton, T. G. Wade and K. B. Jones. 2001. Utilization of Landscape Indicators to Model Potential Pathogen Impaired Waters. *Journal of the American Water Resources Association*. 37(4):805-814.

Snyder, C. D., J. A. Young, R. Villella and D. P. Lemarié. 2003. Influences of Upland and Riparian Land Use on Stream Biotic Integrity. *Landscape Ecology*. 18(7):647-664. (available at http://ipsapp008.kluweronline.com/content/getfile/4969/48/1/fulltext.pdf)

Spence, B. C, G. A. Lomnicky, R. M. Hughes and R. P. Novitski. 1996. *An Ecosystem Approach to Salmonid Conservation*. Report No. TR-4501-96-6057. ManTech Environmental Research Services Corporation. Corvallis, Oregon. 356 pp. (available at http://www.nwr.noaa.gov/1habcon/habweb/habguide/ManTech/front.htm#TOC)

Stelma, G. N. and L. J. McCabe. 1992. Nonpoint Pollution from Animal Sources and Shellfish Sanitation. *Journal of Food Protection*. 55(8):649-656.

Taber, B. and J. Costa. 1998. *Broad Marsh River Stormwater Remediation Project 1993-1998*. DEP Project No. 93-01/319. Prepared for Massachusetts Department of Environmental Protection and U.S. Environmental Protection Agency Region 1. 26 pp. (available at http://www.buzzardsbay.org/download/bmrfinal.pdf)

Tourbier, J. T. and R. Westmacott. 1981. *Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development*. Urban Land Institute. Washington, D.C. 178 pp.

Turner, R. E. 2001. Of Manatees, Mangroves, and the Mississippi River: Is there an Estuarine Signature for the Gulf of Mexico? *Estuaries*. 24(2):139-150.

Turner, R. E. 1994. Landscapes and the Coastal Zone. In: *Environmental Science in the Coastal Zone: Issues for Further Research. Commission of Geosciences, Environment, and Resources*. National Research Council. National Academy Press. Washington, D.C. pp. 85-106. (available at http://www.nap.edu/books/0309049806/html/)

U.S. Department of Agriculture. 2001. *National Resources Inventory: Highlights*. Natural Resources Conservation Service, U.S. Department of Agriculture. Washington, D.C. 3 pp. (available at http://www.nrcs.usda.gov/technical/land/pubs/97highlights.pdf)

U.S. Department of Agriculture. 2000. *Summary Report 1997 National Resources Inventory*. Natural Resources Conservation Service, U.S. Department of Agriculture. Washington, D.C. 90 pp. (available at http://www.nrcs.usda.gov/technical/NRI/1997/summary_report/index.html)

U.S. Department of Commerce. 2001. *Population Change and Distribution: 1990 to 2000*. Publication No. C2KBR/01-2. U.S. Census Bureau, U.S. Department of Commerce. Washington, D.C. 7 pp. (available at http://www.census.gov/prod/2001pubs/c2kbr01-2.pdf)

U.S. Environmental Protection Agency. 2002a. *Considerations in the Design of Treatment Best Management Practices (BMPs) to Improve Water Quality*. Report No. EPA/600/R-03/103. National Risk Management Research Laboratory, U.S. Environmental Protection Agency. Cincinnati, Ohio. 144 pp. (available at http://www.epa.gov/ORD/NRMRL/Pubs/600r03103/600r03103.pdf)

U.S. Environmental Protection Agency. 2002b. Lake Tashmoo Storm Water Remediation Project: First Flush Leaching Basins More Effective Than Expected. In*: Section 319 Success Stories Volume III: The Successful Implementation of the Clean Water Act's Section 319 Nonpoint Source Pollution Program*. Report No. EPA 841-S-01-001. Office of Water, U.S. Environmental Protection Agency. Washington, D.C. p. 74-75. (available at http://www.epa.gov/owow/nps/Section319III/pdf/319_all.pdf)

U.S. Environmental Protection Agency. 2001a. N*ational Coastal Condition Report*. Report No. EPA-620/R-01/005. Office of Water, U.S. Environmental Protection Agency. Washington, D.C. 204 pp. (available at http://www.epa.gov/owow/oceans/nccr/downloads.html)

U.S. Environmental Protection Agency. 2001b. *Our Built and Natural Environments: A Technical Review of the Interactions between Land Use, Transportation, and Environmental Quality*. Report No. EPA 231-R-01-002. Development, Community and Environment Division, U.S. Environmental Protection Agency. Washington, D.C. 93 pp. (available at http://www.epa.gov/smartgrowth/pdf/built.pdf)

U.S. Environmental Protection Agency. 2001c. *Protocol for Developing Pathogen TMDLs: First Edition*. Report No. EPA 841-R-00-002. Office of Water, U.S. Environmental Protection Agency. Washington, D.C. 132 pp. (available at http://www.epa.gov/owow/tmdl/pathogen_all.pdf).

U.S. Food and Drug Administration. 2000. *National Shellfish Sanitation Program, Guide for the Control of Molluscan Shellfish, Model Ordinance*. Office of Seafood, U.S. Food and Drug Administration. Washington, D.C. (available at http://vm.cfsan.fda.gov/~ear/nsspotoc.html)

Valiela, I., K. Foreman, M. Lamontagne, D. Hersh, J. Costa, P. Peckol, B. Demeo-Anderson, C. D'Avanzo, M. Babione, C. Sham, J. Brawley and K. Lajtha. 1992. Couplings of Watersheds and Coastal Waters: Sources and Consequences of Nutrient Enrichment in Waquoit Bay, Massachusetts. *Estuaries*. 15(4):443-457. (available at http://estuaries.olemiss.edu/cdrom/ESTU1992_15_4_443_457.pdf)

van der Wel, B. 1995. Dog Pollution. *Aqua Australis: The Magazine of the Hydrological Society of South Australia*. 2(1):1

Van Dolah, R. F, D. E. Chestnut and G. I. Scott, eds. 2000. *A Baseline Assessment of Environmental and Biological Conditions in Broad Creek and the Okatee River, Beaufort County, South Carolina*. Prepared by South Carolina Department of Health and Environmental Control, South Carolina Department of Natural Resources, and National Oceanic and Atmospheric Administration, National Ocean Service. Final Report to the Beaufort County Council. Beaufort County, South Carolina. 115 pp. (available at http://www.scdhec.gov/eqc/water/html/broadokateerp/title.html)

Vasconcelos, J. 2001. Factors Affecting the Survival of Viruses in Marine Sediment and Seawater. *Puget Sound Notes*. 45:9-12. (available at http://www.psat.wa.gov/Publications/psnotes_pdf/psnotes45.pdf)

Vernberg, F. J. and W. B. Vernberg. 2001. *The Coastal Zone: Past, Present, and Future*. University of South Carolina Press. Columbia, South Carolina. 191 pp.

Vernberg, F. J., W. B. Vernberg, D. E. Porter, G. T. Chandler, H. N. McKellar, G. Scott, T. Siewicki, M. Fulton, D. Bushek, D. Tufford and M. Wahl. 1999. Coastal Development Impacts on Land-Coastal Waters. In: *Land Ocean Interactions: Managing Coastal Ecosystems*. E. Ozhan, ed. Fourth International Conference on the Mediterranean Coastal Environment and Forth International Conference on Environmental Management of Enclosed Coastal Seas, Joint Conference. November 9-13 1999. Antalya, Turkey. pp. 613-622.

Vernberg, F. J., W. B. Vernberg, E. Blood, A. Fortner, M. Fulton, H. McKellar, W. Michener, G. Scott, T. Siewicki and K. El Figi. 1992. Impact of Urbanization on High-Salinity Estuaries in the Southeastern United States. *Netherlands Journal of Sea Research*. 30:239-248.

Vernberg, W. B. 1997. An Overview of the Effects of Urbanization on Estuaries: The Land-Estuarine Interface. *Journal of Experimental Marine Biology and Ecology*. 213(1):ix-x.

Vernberg, W. B., G. I. Scott, S. H. Strozier, J. Bemiss and J. W. Daugomah. 1996. The Effects of Urbanization on Human and Ecosystem Health. In: *Sustainable Development in the Southeastern Coastal Zone*. F. J. Vernberg, W. B. Vernberg and T. Siewicki, eds. The Belle W. Baruch Library in Marine Science, No. 20. University of South Carolina Press. Columbia, South Carolina. pp. 221-239.

Virginia Department of Environmental Quality. 2003. *Little Wicomico River Watershed TMDL for Three Shellfish Areas Listed Due to Bacteria Contamination*. Virginia Department of Environmental Quality. Richmond, Virginia. 28 pp. (available at http://www.deq.state.va.us/tmdl/apptmdls/shellfish/wicomico.pdf)

Vølstad, J. H., N. E. Roth, G Mercurio, M. T. Southerland and D. E. Strebel. 2003. Using Environmental Stressor Information to Predict the Ecological Status of Maryland Non-Tidal Streams As Measured by Biological Indicators. *Environmental Monitoring and Assessment*. 84(3):219-242. (available at http://ipsapp008.kluweronline.com/content/getfile/4674/112/3/fulltext.pdf)

Walker, H. A., J. A. Latimer and E. H. Dettmann. 2000. Assessing the Effects of Natural and Anthropogenic Stressors in the Potomac Estuary: Implications for Long-Term Monitoring. *Environmental Monitoring and Assessment*. 63(1):237-251. (available at http://www.epa.gov/maia/pdf/ema_walker.pdf)

Wang, L., J. Lyons, P. Kanehl and R. Bannerman. 2001. Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spatial Scales. *Environmental Management*. 28:255-266.

Walsh, C. 2002. Avoiding Going Down the Drain. *Watershed*. Cooperative Research Center for Freshwater Ecology. Canberra, Australia. 28:4. (available at http://enterprise.canberra.edu.au/WWW/www-watershed.nsf/0/b1866f5f5ef17b40ca256c84000766e9/$FILE/Watershed+November.pdf)

Washington State Department of Ecology. 2004. *Dungeness Bay Fecal Coliform Bacteria Total Maximum Daily Load Study*. Publication No. 04-03-012. Environmental Assessment Program, Washington Department of Ecology. Olympia, Washington. 38 pp. (available at http://www.ecy.wa.gov/pubs/0403012.pdf)

Washington State Department of Health. 2004. *2003 Annual Inventory: Commercial and Recreational Shellfish Areas of Washington State*. Office of Food Safety and Shellfish Programs, Washington Department of Health. Olympia, Washington. 36 pp.

Washington State Department of Health. 2000. *Sanitary Survey of Similk Bay*. Office of Food Safety and Shellfish Programs, Washington Department of Health. Olympia, Washington. 34 pp.

Washington State Department of Health. 1998. *Lilliwaup Bay Sanitary Survey Report*. Office of Food Safety and Shellfish Programs, Washington Department of Health. Olympia, Washington. 32 pp.

Washington State Office of Financial Management. 2002a. *2002 Population Trends for Washington State*. Washington Office of Financial Management. Olympia, Washington. 66 pp.

Washington State Office of Financial Management. 2002b. *Washington State County Population Projections for Growth Management by Age and Sex: 2000-2025*. Washington Office of Financial Management. Olympia, Washington. 112 pp. (available at http://www.ofm.wa.gov/pop/gma/countypop.pdf)

Washington State Office of Financial Management. 2000. *Population Density Map from Block Level Census Data, 2000*. Washington State Office of Financial Management. Olympia, Washington. (available at http://www.ofm.wa.gov/popden/index.htm)

Washington State Parks and Recreation Commission. 1993. *Dosewallips State Park Shellfish Bed Restoration Project*. Resource Development Division, Washington Parks and Recreation Commission. Olympia, Washington. 50 pp.

Wear, D. N., M. G. Turner and R. J. Naiman. 1998. Land Cover Along an Urban-Rural Gradient: Implications for Water Quality. *Ecological Applications*. 8(3):619-630.

Webster, L. F., B C. Thompson, M. H. Fulton, D. E. Chestnut, R. F. Van Dolah, A. K. Leight and G. I. Scott. 2004. Identification of Sources of *Escherichia coli* in South Carolina Estuaries Using Antibiotic Resistance Analysis. *Journal of Experimental Marine Biology and Ecology*. 298(2):179-195.

Weiskel, P., Howes, B. and G. Heufelder. 1996. Coliform Contamination of a Coastal Embayment: Sources and Transport Pathways. *Environmental Science and Technology*. 30(6):1872-1881.

Wetz, J. J., E. K. Lipp, D. W. Griffin, J. Lukasik, D. Wait, M. D. Sobsey, T. M. Scott and J. B. Rose. 2004. Presence, Infectivity, and Stability of Enteric Viruses in Seawater: Relationship to Marine Water Quality in the Florida Keys. *Marine Pollution Bulletin*. 48(7-8):698-704.

White, D. L., D. E. Porter and A. J. Lewitus. 2004. Spatial and Temporal Analyses of Water Quality and Phytoplankton Biomass in an Urbanized Versus a Relatively Pristine Salt Marsh Estuary. *Journal of Experimental Marine Biology and Ecology*. 298(2):255-273.

White, N. M., D. E. Line, J. D. Potts, W. Kirby-Smith, B. Doll and W. F. Hunt. 2000. Jump Run Creek Shellfish Restoration Project. *Journal of Shellfish Research*. 19(1):473-476.

White, N. M., D. E. Line, J. D. Potts, W. Kirby-Smith, B. Doll and W. F. Hunt. 1998. Jump Run Creek Shellfish Restoration Project. In: Abstracts of Technical Papers Presented at the International Conference on Shellfish Restoration, Hilton Head Island, South Carolina, November 18-21, 1998. *Journal of Shellfish Research*. 17(4):1317.

Young, K. D. and E. L. Thackston. 1999. Housing Density and Bacterial Loading in Urban Streams. *Journal of Environmental Engineering*. 125(12):1177-1180.