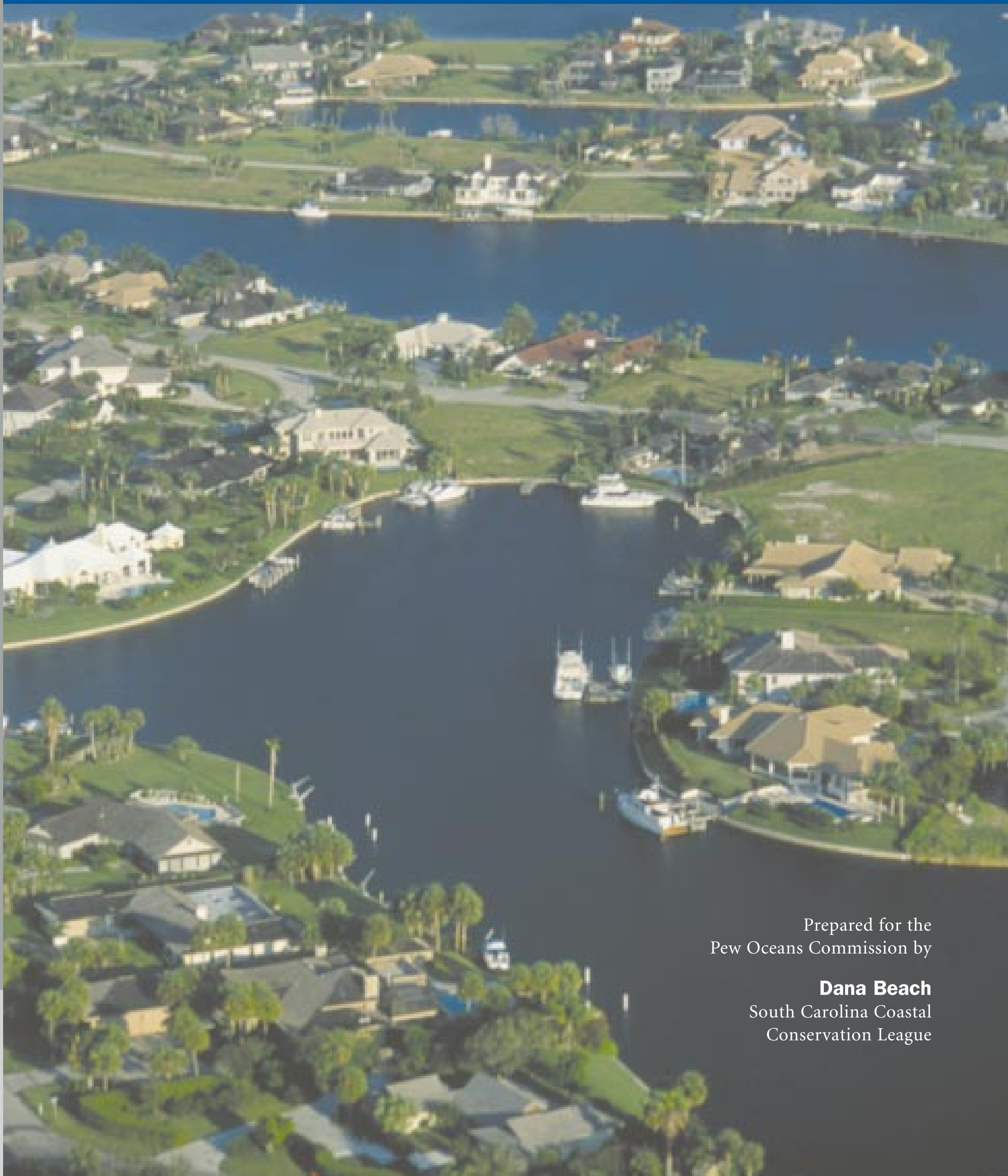
Coastal Sprawl

THE EFFECTS OF URBAN DESIGN ON AQUATIC ECOSYSTEMS IN THE UNITED STATES



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PEW OCEANS COMMISSION

Front and Back Cover: *A scattering of residential homes—a sign of sprawl—dots an aerial view of a Vero Beach, Florida, landscape. Research shows that population growth, runaway land consumption, dysfunctional suburban development patterns, and exponential growth in automobile use threaten the coastal ecology of the United States.*

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Abstract

According to popular wisdom, rapid population growth is the biggest threat to the coastal environment. It's a classic case of trying to put ten pounds of potatoes in a five-pound sack. Or is it? At first glance, national statistics appear to confirm that perspective. Coastal counties cover 17 percent of the land area of the United States. Coastal watersheds, as described by the Department of Agriculture, represent just 13 percent of the nation's acreage. By any measure, the coastal zone is a small part of the country, but it is home to more than half of America's citizens. Moreover, today's coastal populations are just the tip of the iceberg. Over the next 15 years, 27 million additional people—more than half of the nation's population increase—will funnel into this narrow corridor along the edge of the ocean.

Coastal population growth is not the whole story, however. It is actually a short chapter in a much longer book. Runaway land consumption, dysfunctional suburban development patterns, and exponential growth in automobile use are the real engines of pollution and habitat degradation on the coast. Some large coastal metropolitan areas are consuming land ten times as fast as they are adding new residents. Across the country, driving has increased at three to four times the increase in population. If today's land consumption trends continue, more than one-quarter of the coast's acreage will be developed by 2025—up from 14 percent in 1997.

These trends are a prescription for severe ecological damage. Abundant research on rivers and estuaries confirms that when impervious surfaces cover more than ten percent of a watershed, the rivers, creeks, and estuaries they surround become biologically degraded. If today's growth trends continue, many healthy watersheds will cross that threshold over the next 25 years and the U.S. will experience sharp and irreversible declines in the health of coastal waters. If we are to protect coastal ecosystems, reconfiguring and containing growth in the nation's metropolitan regions is not just an option. It is an overriding necessity.

Efforts around the nation to reform development patterns, embodied in such movements as Smart Growth and the New Urbanism, offer solutions to the coastal management challenge. However, the linkage between land-use changes and coastal ecosystem performance is not well understood, nor is it adequately integrated into these broader movements. A large-scale public education campaign targeting local officials, state and federal regulatory agencies and representatives, and the public is a necessary ingredient for success.

Many opportunities exist for implementing change. At the local level, citizen activists are promoting better growth patterns through

improved zoning and public investment policies. States such as Maryland, Florida, and Oregon, continue to refine statewide planning processes in order to achieve growth that is more efficient. Reauthorization of federal transportation, coastal zone management, and water quality legislation is forthcoming. All of these arenas offer the prospect for coordinated policy revisions that protect coastal ecosystems. The potential for positive change is enormous, and the momentum is building. Now is the time to add the cause of coastal ecology, and the voices of coastal protection advocates, to the call for land-use reform.

Coastal Sprawl Glossary

An explosive increase in the growth of phytoplankton is known as an **algal bloom.** The subsequent decay of these organisms can reduce dissolved oxygen levels in the water below the threshold needed by some species of fish and invertebrates.

Coastal sprawl is the expansion of low-density residential and commercial development scattered across large coastal land areas.

The **coastal zone** is often defined as a band stretching 50 miles inland from the ocean. This area hosts half of the U.S. population. The coastal zone can also be defined as land within coastal counties. These counties contain 17 percent of the land area of the contiguous U.S. Coastal watersheds are another helpful way to categorize the coast. These watersheds encompass 13 percent of the contiguous U.S.

Developed land is land in residential, commercial, industrial, or institutional use, or land occupied by urban and suburban amenities, such as golf courses, airports, and landfills.

Geographic Information Systems (GIS) technology stores, manipulates, and displays geographic data. Researchers use GIS to characterize land-use options visually and quantitatively over long periods.

Hypersprawl is the expansion of residential development with housing densities of one unit on three acres or less.

Impervious surface coverage is the percentage or ratio of paved or hardened surface relative to the total land area. Most researchers use this measure to determine how development affects aquatic ecosystems. Impervious surfaces include parking lots, roads, rooftops, and other hard materials that water cannot penetrate.

New Urbanism is the urban design movement that promotes the development of diverse, pedestrian-friendly neighborhoods that offer a range of housing and transportation choices.

Purchase of Development Rights (PDR) programs identify private property important for water quality, wildlife habitat, and other purposes, and provide funds to buy specified development rights from the owners. The easement may, for example, prohibit subdivision and limit construction on the parcel to one house, while allowing the owner to continue to use the the property for forestry, farming, hunting, and other rural activities.

Smart Growth is an environmentally friendly pattern of development that creates livable communities and protects land, water, and animal life.

Total Maximum Daily Loads (TMDLs) determine how much pollution a body of water can accept without becoming degraded.

To curb sprawl and protect open land, some cities and counties in the United States have adopted **Urban Growth Boundaries (UGBs),** which limit land development beyond politically designated areas.

I. Coastal Growth: **Population Trends**

The concentration of people in coastal areas is not a new phenomenon. As long as humans have fished and traded, the coast has been prime real estate. Before the arrival of Europeans in North America, Native Americans settled more heavily along the edge of the continent than in the interior. In 1500, the highest population densities occurred on the West Coast from the current location of the Mexican border to the Canadian border, on the East Coast along the edge of the Chesapeake Bay and from the top of Florida into South Carolina. Native American population densities were also high on the Gulf of Mexico and from Maryland to Cape Cod.

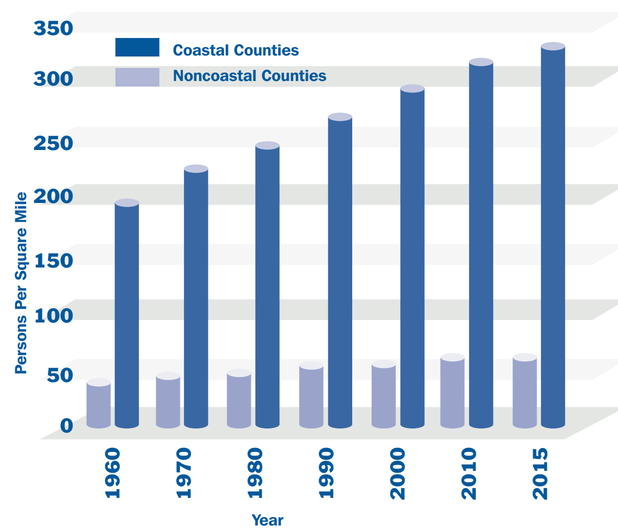
Throughout most of the history of the United States, the coast has contained half or more of the country's residents. Since 1960, coastal counties have accounted for approximately 53 percent of the total U.S. population—a percentage the U.S. Census Bureau predicts will remain constant through 2025 (Culliton, 1998). It is not, then, the changing proportion of population that will define and challenge the coast in the coming decades; it is the unprecedented population increase that will occur within this thin band that borders the sea.

Today the coast is by far the most densely settled part of the country (Figure One).

Figure One

Historical and Projected Densities of Coastal and Noncoastal Counties

For the past 40 years, population density on the coast has been roughly five times that of the country's interior. In 2000, the nation's coastal counties averaged 275 people per square mile. By 2015, the number will rise to 325 people per square mile—an 18 percent increase.



Note: This graph does not include Alaska and Hawaii.
Source: Culliton, 1998.

Fourteen of the nation's 20 largest cities and 19 of the 20 most densely populated counties lie along the coast. Although coastal counties represent just 17 percent of the total acreage of the contiguous U.S., they are home to more than half of the nation's people.

Because the coast will retain its current population share, it will absorb more than half of the U.S.'s population growth in the coming decades. In absolute terms, these increases are substantial. Between 1998 and 2015, the number of coastal residents is projected to swell from 139 million to 165 million—an increase of almost 20 percent.

Nine of the ten largest population gains predicted between 1994 and 2015 occur in coastal counties—five in California, three in Florida, and one in Texas. During the mid-1990s, Florida saw an additional 4,400 new residents every week. The population in southern California has increased by 4,000 people a week and is expected to grow by 5.6 million people over the next 20 years. The population of this region is projected to rise to 24 million by 2015, roughly the population of the entire state of California in 1981 (Culliton, 1998).

At more than five times the density of the interior of the country, coastal population pressure is already great. Over the coming decades, the pressure will rise substantially.

Factors Magnifying the Impacts of Population Growth

Population statistics are commonly used as a proxy to describe the magnitude of human impacts to the environment. However, the number of people in a region only partially determines environmental health. Other factors include what these people do, where they live, and how they get around. As scientist and author Paul Ehrlich noted, environmental impact is a function of population, affluence, and technology. By most measures, human impacts to coastal ecosystems have grown faster than the rate of population growth. So, although population statistics paint an alarming picture for coastal management, they actually understate the magnitude of the challenge.

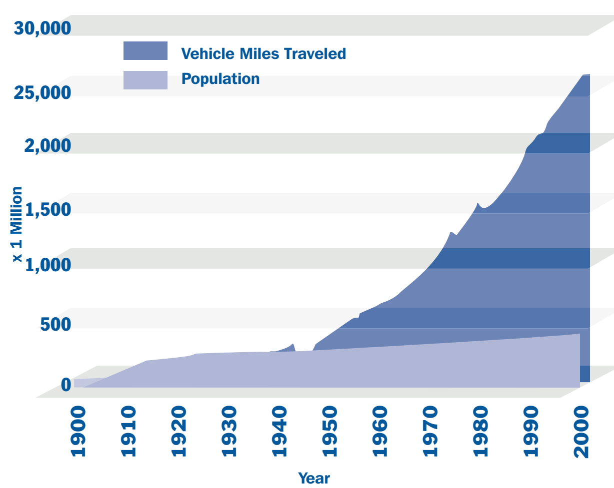
Many coastal areas are major tourist destinations. Population data do not include the large numbers of seasonal visitors to such places as Florida, New Jersey, and Cape Cod. In 1997, there were almost 500,000 seasonal homes on the northeastern seaboard (Culliton, 1998). Consequently, census data understate the population and development impact in many coastal areas.

Per capita, coastal residents are consuming more land, driving more, boating more, and generally using more resources than they were

Figure Two

Increases in Vehicle Miles Outstrip Increases in Population

The number of miles Americans have driven annually over the past 20 years has increased at four times the rate of population growth. Suburban development patterns have contributed to this trend.



Sources: Compiled by Michelle Garland, Surface Transportation Policy Project; Federal Highway Administration, Office of Highway Information Management. Highway Statistics Summary to 1995; Federal Highway Administration, Office of Highway Information Management. Highway Statistics Series, 1995 to 1999; Federal Highway Administration, Office of Highway Information Management. Traffic Volume Trends, December 2000; United States Census Bureau. Historical National Population Estimates: July 1, 1900 to July 1, 1999; United States Census Bureau. Monthly Population Estimates, 1990 to 2000.

30 years ago. Although this is true nationally, it is exaggerated on the coast, which is wealthier than the nation as a whole. In 1994, 18 of the top 20 counties ranked by per capita income were coastal counties (Culliton, 1998).

"As populations have spread out, driving distances have lengthened."

Broward County, in south Florida, illustrates the trend in driving. Between 1983 and 1997, Broward's population grew by 38 percent and the number of licensed drivers increased by 31 percent. However, the number of miles driven on county freeways increased by 177 percent, more than four times the rate of population increase and five times the increase in the number of drivers (Wallis et al., 2001). This increase tracks the national trend in driving. (Figure Two).

As populations have spread out, driving distances have lengthened. Nationally, the average commuter trip was 20 percent longer in 1995 than in 1983. Further, more driving has produced more traffic congestion and slower average driving speeds in many coastal areas. In the Miami area, for example, interstate highway travel speeds dropped from 53 to 41 miles per hour—a 23 percent decline—between 1983 and 1997 (Wallis et al., 2001). All of this translates into more fuel used for transportation, an increase in air and water pollution, and stresses on coastal ecosystems that are even greater than population growth statistics would suggest.

II. Trends in Urban Expansion

The most obvious manifestation of growth is the physical expansion of metropolitan regions and coastal resort areas—the strips of restaurants, gas stations, and car dealerships that line the major roads of all coastal cities, and the vast expanses of housing subdivisions visible from the air. It is not obvious, however, that this expansion of developed land and paved surfaces is unprecedented and that its continuation will have disastrous effects on coastal ecosystems.

Chapter 3 explains in detail how development in coastal watersheds degrades the creeks and marshes that run through them. It draws on many studies that conclude that once pavement and roofs cover ten percent of a watershed's acreage, the health of aquatic ecosystems begins to decline. This chapter explores how quickly coastal watersheds are being developed, and how many regions will pass the threshold of damage in the next 25 years.

According to the U.S. Department of Agriculture's National Resources Inventory (NRI), developed land in the contiguous U.S. increased by 25 million acres, or 34 percent, between 1982 and 1997 (NRI, 2001). This means that more than one-fourth of all of the land converted from rural to urban and suburban uses since European settlement occurred in only 15 years. This 25-million-acre expansion represents an area roughly the size of Ohio. During the same 15-year period, between 1982 and 1997, population grew by about 15 percent (U.S. Census Bureau, 2000). Thus, land consumption occurred at more than twice the underlying rate of population growth. In addition, the mismatch between land development and population growth is widening. Between 1982 and 1992, land was developed at 1.8 times the rate of population growth. During the period between 1992 and 1997, that multiple had grown to 2.5 (NRI, 2001; U.S. Census Bureau, 2000).

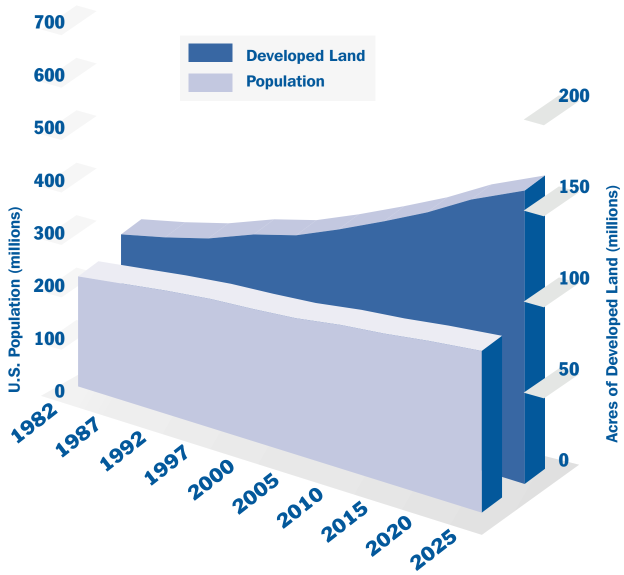
Between 2000 and 2025, the U.S. population is projected to grow by 22 percent. If the relationship between land use and population in the last decade continues, there will be 68 million more acres of developed land in the contiguous U.S. than there are today (Figure Three). This newly developed acreage—equivalent to the land area of Wyoming—will almost match the amount of land developed from the founding of the country until 1983. (For an explanation of how developed land relates to impervious surface coverage, see Box One on page 12.)

Many coastal metropolitan areas experienced more rapid expansion than did the nation as a whole. Between 1982 and 1997, for example, the metropolitan population of New Orleans declined by 1.4 percent, but its urban area expanded by 25 percent (Fulton et al., 2001). Similarly, the New York region's population grew 8 percent between 1970 and 1990, while urban land increased by 65 percent (Diamond and

Figure Three

The Rate of Land Development and the Rate of Population Growth

Land in the United States has been developed at more than twice the rate of population growth since 1982. This increase is a result of a consistent decline in development densities over the past few decades. If this trend continues through the year 2025, the nation will consume another 68 million acres of rural land—an area the size of the state of Wyoming. The total developed land in the United States will reach 174 million acres by 2025—an area larger than the state of Texas.



Sources: Data and extrapolations from National Resources Inventory, 2001; U.S. Census Bureau, 2000.

"If these trends continue, more than one-quarter of the nation's coastal watersheds will be developed by 2025."

Noonan, 1996). From 1973 to 1994, the urban area of Charleston, South Carolina, expanded from 45,000 acres to 160,000 acres—a 250 percent increase. Yet population grew at a much more modest rate of 40 percent (Allen and Lu, 2000). New Orleans, New York, and Charleston, South Carolina, exemplify a national trend. Developed land is spreading at rates dramatically higher than the underlying rate of population growth (Figure Four).

Because the coast hosts more than half of the U.S. population on less than one-fifth the nation's land area, the impact of land conversion is greatly magnified. In 1982, developed land covered 53 million acres, or 3 percent of the noncoastal watersheds in the contiguous U.S. In contrast, 10 percent of the acreage of coastal watersheds was developed. By 1997, 71 million acres, or 4.2 percent, of the interior of the United States was developed. The coastal portion had risen to 27 million acres, or 13.7 percent of the land area.

These percentages varied with each region of the country. The coastal watersheds of the mid-Atlantic region were 30 percent developed in 1997, up from 22 percent in 1982. New England's coastal watersheds were the second most heavily developed, at 17 percent in 1997, followed by California's at 15 percent, and the South Atlantic/Gulf region at 12.5 percent. In contrast, development covered no more than 10.5 percent of any region's noncoastal watersheds.

If these trends continue, more than one-quarter of the nation's coastal watersheds will be developed by 2025. The mid-Atlantic region would see development covering more than 60 percent of its coastal watersheds, while between 25 and 30 percent of the coastal watersheds of New England, California, and the South Atlantic/Gulf regions would be developed. As a point of comparison, only four states in the nation presently have more than one-quarter of their land area developed.

If developed land were expanding at the same rate as population, coastal zone management would be a formidable task. With development vastly outstripping even the relatively high rate of population growth, the challenge is considerably greater.

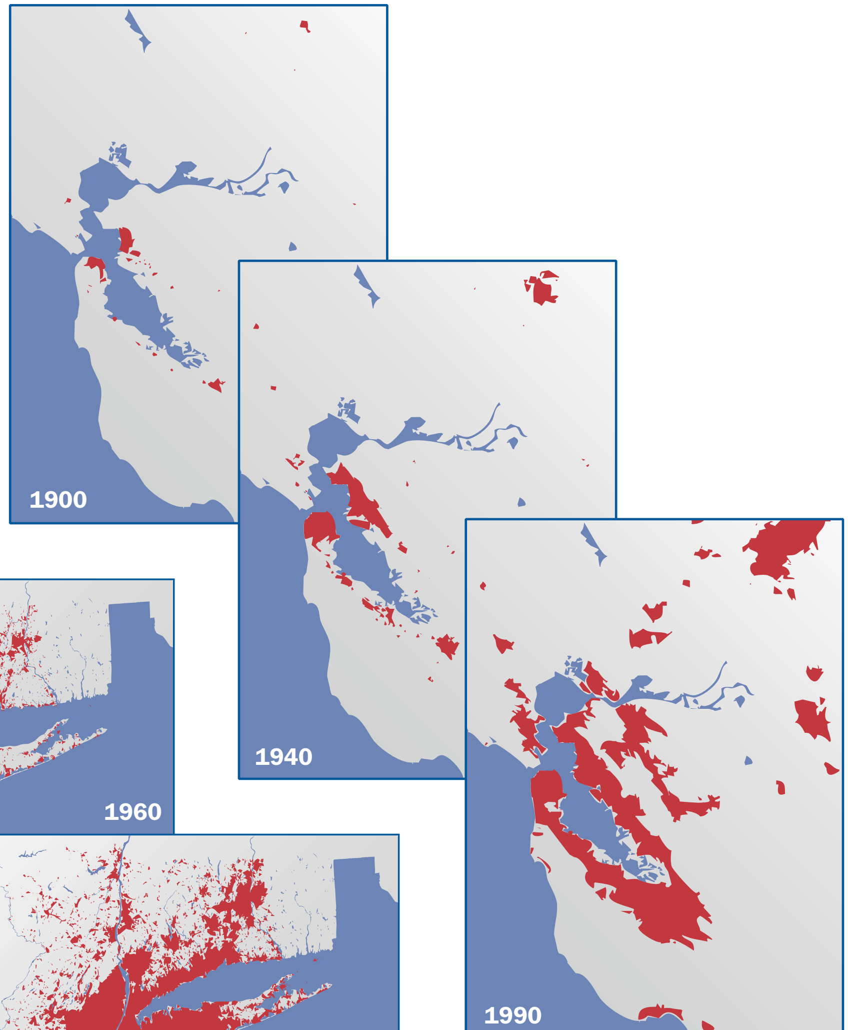
Figure Four

Expansion of Metropolitan Coastal Areas

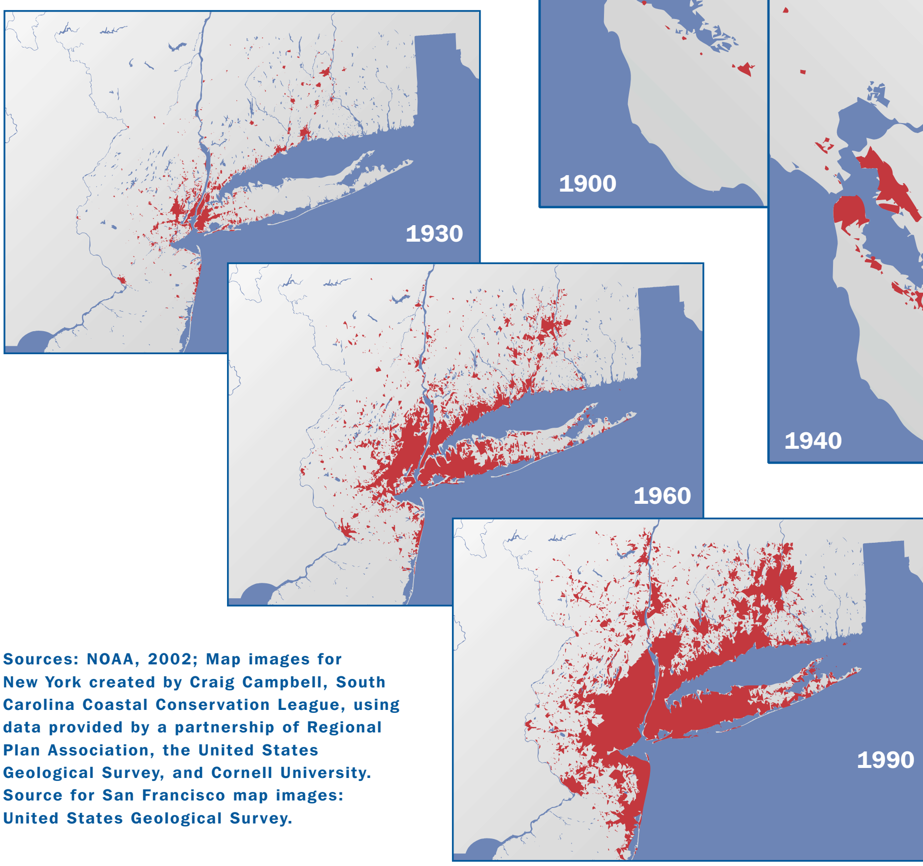
Geographic Information Systems (GIS) technology has recently made it possible to graphically depict the expansion of metropolitan areas.

The developed "footprints" (in red) of many coastal regions are expanding faster than the national average. The metropolitan regions of San Francisco, California, and New York City experienced physical growth rates far in excess of population growth.

San Francisco Bay Area



New York Metropolitan Area



Sources: NOAA, 2002; Map images for New York created by Craig Campbell, South Carolina Coastal Conservation League, using data provided by a partnership of Regional Plan Association, the United States Geological Survey, and Cornell University. Source for San Francisco map images: United States Geological Survey.

III. Urban Growth and the Science **of Watershed Protection**

Land conversion rates are profoundly important in light of recent research on aquatic ecosystems. A variety of studies during the past decade converge on a central point: When more than ten percent of the acreage of a watershed is covered in roads, parking lots, rooftops, and other impervious surfaces, the rivers and streams within the watershed become seriously degraded (Figure Five).

These studies cover a wide range of topics. They examine changes in particular pollutant levels, changes in the physical structure of streams and creeks, and changes in the number of species and the abundance of aquatic life. By virtually every measure of ecosystem health, the streams, creeks, marshes, and rivers surrounded by hardened watersheds are less diverse, less stable, and less productive than those in natural watersheds. If the percentage of the coast that is developed rises sharply (from 14 percent to 25 percent) over the next 25 years, these studies point to an irreversible decline in coastal aquatic ecosystem health. (It is important to note that impervious surface is not synonymous with developed land. See Box One on page 12.)

Much of the beauty of America's coastal ecosystems is their variety from state to state and region to region. However, this variety limits how precisely scientific conclusions from one place can be applied to other areas. Abundant rainfall in the Southeast creates very different patterns of runoff than does the arid climate of southern California. Northern New England's massive tides are vastly different from the gentle oscillations of the Gulf of Mexico. Tide, climate, and geology all shape unique relationships between land and water along the nation's coast.

Consequently, no single field site can characterize coastal ecosystems in general. Further, much of the scientific literature about watershed development covers freshwater, not saltwater, systems. Therefore, the ten-percent rule should not be viewed as sacrosanct. It is entirely possible that future studies of estuaries will derive damage thresholds higher than ten percent, as a few of the recent studies do. It is also possible that future studies will identify more subtle long-term changes that begin at impervious coverage below ten percent. One comparison of two streams in Georgia, for example, found early signs of channel erosion and instability when impervious cover was five percent (Walker, 1996). Additional studies should be conducted to advance our understanding of the link between land use and ecosystem health. As more research is completed, it may be possible to derive different damage thresholds for different coastal ecosystems.

Nevertheless, the unprecedented rate of land conversion demands action now. We must adopt policies today so that changes will begin to emerge in this decade. As always, we must act with incomplete knowledge. The great majority of research to

Figure Five

Impervious Surfaces Affect Aquatic Ecosystems

Studies on aquatic ecosystems over the past 20 years converge on a central point. When more than ten percent of the acreage of a watershed is covered in roads, parking lots, rooftops, and other impervious surfaces, the rivers and streams within those watersheds become seriously degraded.

Reference	Year	Location	Biological Parameter	Key Finding
Booth	1991	Seattle	Fish habitat/ channel stability	Channel stability and fish habitat quality declined rapidly after 10% imperviousness.
Galli	1994	Maryland	Brown trout	Abundance and recruitment of brown trout declines sharply at 10% to 15% imperviousness.
Benke et al.	1981	Atlanta	Aquatic insects	Negative relationship between number of insect species and urbanization in 21 streams.
Jones and Clark	1987	Northern Virginia	Aquatic insects	Urban streams had sharply lower diversity of aquatic insects when human population density exceeded 4 persons per acre. (estimated 15% to 25% impervious cover)
Limburg and Schimdt	1990	New York	Fish spawning	Resident and anadromous fish eggs and larvae declined sharply in 16 tributary streams greater than 10% imperviousness.
Shaver et al.	1994	Delaware	Aquatic insects	Insect diversity at 19 stream sites dropped sharply at 8% to 15% imperviousness.
Shaver et al.	1994	Delaware	Habitat quality	Strong relationship between insect diversity and habitat quality; majority of 53 urban streams had poor habitat.
Schueler and Galli	1992	Maryland	Fish	Fish diversity declined sharply with increasing imperviousness, loss in diversity began at 10% to 12% imperviousness.
Schueler and Galli	1992	Maryland	Aquatic insects	Insect diversity metrics in 24 subwatersheds shifted from good to poor over 15% imperviousness.
Black and Veatch	1994	Maryland	Fish/insects	Fish, insect, and habitat scores were all ranked as poor in 5 subwatersheds that were greater than 30% imperviousness.
Klein	1979	Maryland	Aquatic insects/fish	Macroinvertebrate and fish diversity declines rapidly after 10% imperviousness.
Luchetti and Fuersteburg	1993	Seattle	Fish	Marked shift from less tolerant coho salmon to more tolerant cutthroat trout populations noted at 10% to 15% imperviousness at 9 sites.
Steedman	1988	Ontario	Aquatic insects	Strong negative relationship between biotic integrity and increasing urban land use/riparian condition at 209 stream sites. Degradation begins at about 10% impervious surface.
Pedersen and Perkins	1986	Seattle	Aquatic insects	Macroinvertebrate community shifted to chironomid, oligochaetes, and amphipod species tolerant of unstable conditions.
Steward	1983	Seattle	Salmon	Marked reduction in coho salmon populations noted at 10% to 15% imperviousness at 9 sites.
Taylor	1993	Seattle	Wetland plants/amphibians	Mean annual water fluctuation was inversely correlated to plant and amphibian density in urban wetlands. Sharp declines noted over 10% imperviousness.
Garie and McIntosh	1986	New Jersey	Aquatic insects	Drop in taxa from 13 to 4 noted in urban streams.
Yoder	1991	Ohio	Aquatic insects/fish	100% of 40 urban sites sampled had fair to very poor index of biotic integrity scores.

Source: Schueler and Holland, 2000.

date concludes, as this chapter will explain, that the impervious coverage threshold for damage is about ten percent. The ten-percent rule, then, must be our starting point for reform. Here are some of the reasons why.

"... a one-acre parking lot produces about 16 times the volume of runoff that comes from a one-acre meadow."

Habitat Quality

The most obvious change caused by development is that rainwater flows faster across the ground, and more of it reaches creeks, rivers, and estuaries in the form of runoff. Illustrating this change, a one-acre parking lot produces about 16 times the volume of runoff that comes from a one-acre meadow (Schueler and Holland, 2000).

These magnified "pulses" of runoff alter the stream flow patterns and, consequently, the shape of the stream channel. Streams in watersheds with more than ten percent hard surfaces become physically unstable, causing erosion and sedimentation (Booth, 1991; Booth and Reinelt, 1993). In addition, natural habitats such as pools, woody debris, and the wetted perimeter of the streambed decline (Booth and Reinelt, 1993; Shaver et al., 1995). Overall, habitat quality falls below the level necessary to sustain a broad diversity of aquatic life.

Water Temperature

As runoff flows across paved roads and parking lots into coastal marshes, water temperature rises—the more impervious surface area in the watershed, the hotter the water (Galli, 1991). This is particularly true in small tidal creeks. Because these areas are often naturally low in dissolved oxygen, further increases in temperature can push oxygen levels toward zero, especially in the summer. The upper reaches of tidal creeks and marshes serve as nursery grounds for many finfish and shellfish that inhabit coastal waters, so the dissolved oxygen balance of these areas has great implications for the health of the marine environment.

Pollutants

When impervious coverage in the watershed reaches ten percent, water quality also suffers. Urban runoff transports a vast assemblage of pollutants into the aquatic environment, including sediment; nutrients such as nitrogen and phosphorus; organic carbon; trace metals such as copper, zinc, and lead; petroleum hydrocarbons; and pesticides (Schueler and Holland, 2000).

The growth of plants in estuarine systems is generally controlled by the amount of available nitrogen. Consequently, additional nitrogen from coastal development can cause algal blooms. The subsequent decay of these organisms can reduce dissolved oxygen levels below the threshold needed by some species of fish and invertebrates. Additionally, overfertilization reduces water clarity and allows less light to penetrate below the water's surface. This damages seagrass beds, coral reefs, and other critical aquatic habitats. The primary sources of nitrogen in most developed watersheds are lawns, golf courses, and automobile tailpipes, along with significant contributions from municipal wastewater treatment plants. In the Gulf of Mexico at the mouth of the Mississippi River, inland sources of nutrients, primarily from agricultural activities (Boesch et al., 2001), have depleted oxygen in vast areas of coastal waters, devastating aquatic life in that area. Nationwide, though, the health of coastal waters is more affected by human activities much closer to the coast.

Lawns cover 20 to 30 million acres of the American landscape. Research in a number of states concludes that 70 percent of all lawns are regularly fertilized. Most of these lawns have not been tested to determine whether they need (and can absorb) additional nitrogen (Schueler and Holland, 2000). Further, as much as 25 percent of the nitrogen added to coastal estuaries comes from atmospheric deposition (Boesch et al., 2001), much of which originates from motor vehicles. Consequently, nitrogen is one of the most widespread contaminants in the nation's waters.

Once impervious surfaces pass approximately ten percent of the total acreage of a watershed, nitrogen begins to exceed background levels (Schueler and Holland, 2000). The USGS National Assessment of Nutrient Levels concludes that urban streams have the second highest levels of nitrates and phosphorus, exceeded only by waters adjacent to row-crop agriculture (Smith et al., 1992). Trapping sediments in detention ponds can contain insoluble phosphorus, which is usually associated with sediments. Water-soluble nitrogen is much more difficult to contain with these methods. This makes land-use strategies essential in protecting coastal estuaries from nutrient pollution.

Cars and trucks appear to be one of the largest sources of metals in estuaries and nearshore waters. A study of the lower San Francisco Bay found that half of the cadmium and zinc in the bay came from tire wear. Lead came primarily from diesel-fueled vehicles. Half of the copper in the bay arrived via stormwater from brake pad wear. An additional 25 percent of the copper arrived in the form of atmospheric deposition, ultimately from motor vehicles. Copper contamination is a major concern because copper is toxic to marine organisms at extremely low concentrations (Santa Clara Valley Nonpoint Source Control Program, 1992). In Maryland, studies in suburbanized watersheds with little industrial activity revealed that metals from lawns, roads, and automobiles accumulated in sediments at levels toxic to aquatic life (Hartwell et al., 2000).

A number of studies have focused on the connection between automobile usage and stormwater pollution. Generally, these studies have found that higher traffic volumes translate into higher levels of pollutants. Commercial parking lots and high-traffic streets contribute a disproportionate amount of the total pollutant load. In one study, for example, parking lots and major streets covered 6 percent of the watershed but contributed about a quarter of the metals and 64 percent of the petroleum hydrocarbons (PAHs) produced in the watershed (Steuer et al., 1997).

Aquatic Life

The ten-percent rule applies to aquatic life, which is the ultimate measure of ecosystem health. Some of the earliest research on watershed coverage focused on aquatic insects. This work concluded that the diversity of macroinvertebrates like stoneflies, mayflies and caddis flies falls sharply when imperviousness exceeds ten percent (Klein, 1979). These organisms represent the base of the food chain on which fish and other wildlife depend. Later studies derived similar results.

Studies of fish reinforce the proposition that paved watersheds fail to support a natural diversity of species. Particularly affected groups include trout, salmon, and other species of anadromous fish.

"The ten-percent rule applies to aquatic life, which is the ultimate measure of ecosystem health."

These sensitive species disappeared as impervious surfaces covered 10 to 12 percent of the watershed. Impervious watersheds created barriers to migration for anadromous species, illustrated by sharp declines in eggs and larvae in hardened watersheds (Schueler and Holland, 2000). Research by the Maryland Department of Natural Resources also concluded that urbanization of watersheds correlates with reduced fish communities (Carmichael et al., 1992).

"... current environmental policies can encourage hypersprawl as a solution to nonpoint source pollution."

Studies specifically focusing on coastal estuaries have confirmed that general degradation begins at the ten-percent impervious threshold (Taylor, 1993). Recent research in small watersheds around Charleston, South Carolina, draws similar conclusions. When impervious surfaces exceed 15 to 20 percent, the variety and abundance of food available for juvenile fish is significantly reduced (Holland et al., 1996).

The ten-percent threshold of imperviousness translates into housing densities in the range of one unit per two to three acres. However, lower-density development on individual septic systems can also cause significant alterations in aquatic ecosystems. Studies suggest that development on septic tanks at densities greater than one unit per seven acres produces enough bacterial pollution to close shellfish beds (Duda and Cromartie, 1982).

Interpreting the Ten-Percent Rule

The principle of the ten-percent impervious threshold is central to creating marine ecosystem protection programs. Some marine pollutants, such as phosphorus, can be captured and treated using Best Management Practices (BMPs), raising the threshold of degradation from those pollutants above ten percent. Other pollutants, such as pesticides and nitrates, are extremely mobile and difficult to contain and treat. This is particularly important for coastal waters, where nitrogen is the primary limiting ingredient for algal growth. However, the utility of the rule is not so much its predictive value for a single pollutant or physical impact. Instead, the ten-percent threshold establishes an empirical point beyond which ecosystem function, in general, declines because of individual and cumulative stresses.

Considered in isolation, the ten-percent rule could be interpreted to mean that the ideal pattern of growth is hypersprawl—with housing at densities of one unit per three acres or less (Box One). Moreover, to avoid septic contamination of ground and surface waters, houses would be served by a central sewer system. This arrangement is unsustainable in a variety of ways. It is fiscally unsustainable because local service costs would far exceed tax revenues. It is socially unsustainable because housing in these configurations would be prohibitively expensive for a large segment of the population. It is environmentally unsustainable because it would ensure total dependence on automobiles, accelerate the conversion of rural land, and fragment terrestrial wildlife habitats. In spite of these considerations, current environmental policies can encourage hypersprawl as a solution to nonpoint source pollution. As Chapter 4 explains, the real solution is not uniform low-density development across metropolitan regions. Instead, optimal development patterns for marine protection would be similar to those advocated by Smart Growth proponents and New Urbanists, but the development patterns would be shaped by regional watershed protection plans.

Box One

Translating Developed Land into Impervious Surface

Impervious surface coverage is the measure used by most researchers to determine how development affects aquatic ecosystems. Impervious surfaces include parking lots, roads, rooftops, and other hard materials that water cannot penetrate. However, national land-use data, as compiled by the Department of Agriculture (USDA), describes land as "developed" or "undeveloped." For the USDA, developed land is land that is urban or suburban, including porous surfaces such as lawns, small urban parks, and golf courses, in contrast to land that is rural, with farms and forests. Developed land coverage, then, is not the same as impervious surface coverage.

Consequently, it is important to understand how the percentage of the watershed that is classified as developed relates to the percentage that is covered with impervious surfaces. A city such as New York or San Francisco has a very high percentage of impervious coverage, probably above 90 percent. In these cities, the percentage of land classified as developed would be close to the percentage of land that is impervious. Suburban development, on the other hand, has considerably lower percentages of impervious coverage.

Although suburban development comes in a multitude of forms, a rough approximation of the impervious coverage associated with typical single-family development—three to five units per acre—is 40 percent. To derive the amount of imperviousness from statistics on developed land, multiply by 0.4. (Thus, the projected 68-million-acre increase in developed land over the next quarter century implies that impervious surfaces such as roads, parking lots, and rooftops would expand by 25 million acres or more.) A suburban watershed that is 50 percent developed, for example, would be 20 percent impervious—and in ecological trouble. The development threshold for ecological damage in a watershed dominated by conventional suburban development is 25 percent (25 percent multiplied by 0.4 equals 10 percent).

Should we establish a policy limiting suburban development to 25 percent of the watershed, with the remainder in undeveloped land? Like the hypersprawl solution of three-acre lots, this approach is a blind alley. First, cities do not, and should not, grow as clumps of development surrounded by open land. A seamless, fine-grained pattern of urban land uses has characterized great and functional cities for thousands of years. Transportation efficiency and local service costs are two of the many reasons this is so. Second, the wide disparity in land value between developable and undevelopable land in a single watershed would create a political knot that could only be untangled through public purchase of the land to be left open, at costs no city or state could afford. Ultimately, this approach to protecting aquatic ecosystems, like the three-acre lot strategy, runs counter to almost all of the goals, functions, and traditions of real cities.

As the next two chapters will demonstrate, protecting coastal ecosystems requires different patterns of growth at the regional and neighborhood scales, not micromanaging the percentage of each watershed that is covered by impervious surfaces. These patterns reflect the reforms promoted by New Urbanism and Smart Growth, and are further refined by regional watershed analysis and planning.

IV. Strategies and Tools for Protection

Population and land-use data, combined with abundant research on the science of watersheds, make it clear that land-use reforms are necessary to preserve coastal ecosystems. These reforms must begin in the first half of this decade to avert severe and irreversible declines in ecosystem function. The critical questions we must ask are these: Which development patterns can sustain aquatic ecosystems? If sprawl will not work, what will? How do we put the necessary land-use changes in practice throughout America's coastal regions?

It is helpful to group land-use reforms by the scale of application. First, there is the issue of where development will occur within a metropolitan region. A metropolitan region can encompass a dozen watersheds and cover two million acres of land or more. This is the regional scale. Second, there is the issue of how development is organized—what street patterns are laid out, and how different land uses are arranged and at what densities. This is the neighborhood scale. Third, there is the issue of how development projects are constructed—what stormwater practices, paving types, riparian buffer widths will be employed. This is the site scale.

Ecosystem preservation depends on successfully reforming development at each of these scales. Traditionally, regulatory programs have operated almost exclusively at the site level. Independently, land-use reformers have worked at the regional scale promoting strategies such as urban growth boundaries (UGBs) and farmland protection programs. Until recently, the neighborhood scale received very little systematic attention, yet like the regional and site scale, it is profoundly important in the effort to protect marine ecosystems.

Regional Scale

We know from the national land-cover data that 14 percent of the coast is developed. Current development trends will raise this to 25 percent by 2025. According to the ten-percent rule, if the coast were a single watershed, it would take 25 years to move into the danger zone. But the coast consists of tens of thousands of watersheds, some with impervious coverage that is close to 100 percent, and some virtually undeveloped. The central principle of a marine-protection strategy must be to identify those watersheds that are less than 10 percent impervious and attempt to maintain most of them in an undeveloped state. The companion principle is that watersheds with imperviousness of more than 10 percent should absorb the majority of coastal growth over the coming decades.

This does not imply that we must sacrifice developed watersheds. On-site stormwater practices, buffers, new paving techniques, reduced automobile dependency, and other reforms at the neighborhood and site levels can help maintain these systems. Section 6217 of the Coastal Zone Management Act specifies on-site stormwater practices that can effectively reduce pollutant loads and environmental impacts from development. However, the current inventory of on-site safeguards does not allow us to ignore the ten-percent rule. The only aquatic systems that will retain the full range of species and ecological functions will be those where less than ten percent of the watershed is impervious (Schueler and Holland, 2000). The goal, therefore, must be to maintain as many of those systems as possible.

Mapping technology and satellite imagery now allow each metropolitan region to inventory its undeveloped watersheds. Further, regions can analyze the development potential within watersheds that are already impaired. These two elements provide the information necessary for a region to adopt land-use policies that steer development into the best locations, thereby protecting coastal ecosystems.

Once regions determine the best locations for new development (developed and developing watersheds), and the locations in which development should be minimized (watersheds which are less than ten percent impervious), localities and the state must adopt policies to carry out those plans. The tools to do this fall into three categories: zoning codes, infrastructure planning, and land-protection programs. These tools can be applied to communities of any size, from small rural towns to multistate metropolitan areas.

Agricultural Zoning and Urban Growth Boundaries

In the last few decades, some communities have attempted to control the spread of urban areas by regulating development and subdivision densities in rural areas. One early example is Oregon's 1973 land-use planning act, which required each town and city to set urban growth boundaries (UGBs) large enough to absorb 20 years of projected growth. Beyond the UGBs, agricultural zoning set minimum lot sizes of 80 acres, considered the smallest necessary to support agriculture. Localities throughout the country, from Virginia to California, have established rural zoning at similarly low densities.

In some localities, "agricultural" zoning allows development in the range of one unit per two acres. These types of large-lot requirements have been widely criticized as accelerating sprawl. Circumstances vary across the country, but certain principles should guide regions as they adopt agricultural zoning codes. First, the codes should advance the legitimate interests metropolitan regions have in sustaining farming and forest uses, protecting marine and other aquatic ecosystems from degradation, minimizing the costs of delivering urban services, and other regional goals. In most cases, housing densities in undeveloped areas should be lower than one unit per 20 acres.

Agricultural zoning and urban growth boundaries can backfire if municipalities do not support development within their jurisdictions at reasonable densities. If, for example, local governments zone primarily for half-acre lots or larger, the land available for growth would be quickly used up. This would increase land and housing prices and would force development into rural areas and undeveloped watersheds. For this reason, agricultural zoning should accompany strategies like Oregon's 1975 state planning provision that localities zone to allow for adequate growth within their boundaries.

"The only aquatic systems that will retain the full range of species and ecological functions will be those where less than ten percent of the watershed is impervious."

"Coordinated efforts between land trusts and federal, state, and local governments can be extremely effective in protecting large watersheds."

Infrastructure Planning

Public investment in new roads, sewerage, waterlines, rapid-response fire protection, and other urban services accelerate development in areas that would otherwise remain rural. With that in mind, some localities have attempted to dampen the spread of development into rural areas by withholding urban infrastructure. Lexington, Kentucky, adopted one of the nation's first urban service boundaries in 1958.

The state of Maryland recently passed statewide growth-management legislation that guides public investment into areas already developed or approved for urban expansion. Public investment is withheld from rural areas that are not judged appropriate or necessary for new growth.

Each year, federal and state agencies provide billions of dollars through grants and loans for infrastructure in rural areas. Notable examples include highway funds, rural sewerage and waterline funding from the Department of Agriculture and the U.S. Environmental Protection Agency (EPA), and flood insurance through the Federal Emergency Management Agency. These projects are frequently not reviewed in light of regional growth plans, yet they have great potential to undermine growth-management goals and needs. To protect marine and coastal ecosystems effectively, all infrastructure spending must be held to the same standards of consistency with regional growth plans.

Land Conservation Programs

Many state and local governments are attempting to channel urbanization away from important rural areas by using public funds to purchase development rights from the owners of strategic parcels. These Purchase of Development Rights, or PDR, programs identify important farm and forest lands and provide funds to remove the development rights from the parcels. In some cases, land is purchased outright and becomes a part of the region's inventory of public recreational property. Localities often operate PDR programs jointly with private land trusts, which negotiate sales, hold easements, and supplement public funds with private funds.

Approximately 1,200 land trusts operate in the U.S. These organizations purchase or solicit donated easements on private land holdings and broker conservation purchases of property. As of December 31, 2000, local land trusts had protected a total of 6.4 million acres of land nationwide. National land trusts, such as The Nature Conservancy, Ducks Unlimited, the Conservation Fund, and the Trust for Public Lands, have protected more than 15 million acres.

Coordinated efforts between land trusts and federal, state, and local governments can be extremely effective in protecting large watersheds. The Ashepoo/Combahee/Edisto (ACE) basin initiative on the coast of South Carolina, for example, has permanently protected 150,000 acres out of the total project area of 350,000 acres in just 13 years.

Regional Scale Summary

Regions must decide how to employ these strategies most effectively to influence the location of new development. The most successful efforts to contain urban growth will almost certainly be in those *areas that apply the full assortment of tools available, including zoning, infrastructure planning, and land purchase and private conservation across the metropolitan region.*

All of these programs are designed to prevent sprawl into rural areas. Private easements sometimes prescribe ecological management practices for the lands they cover. Agricultural zoning codes and urban service boundaries, on the other hand, are silent on the question of how rural lands are managed. Because rural land-use practices, such as row-crop agriculture, can contribute volumes of pollutants that equal or exceed urban land uses, marine protection strategies must also focus on land management outside of urban areas.

A detailed analysis of agricultural and silvicultural impacts on coastal ecosystems is beyond the scope of this paper. However, it is important to note that best management practices such as nutrient management, rotational grazing, integrated pest management, and buffer strips can substantially reduce the pollutant load from agricultural land uses. These types of practices are essential to healthy aquatic systems. Confined animal feeding operations (CAFOs) have caused enormous environmental damage in some coastal areas. A single large factory hog farm, for example, can produce enough nitrogen to destroy aquatic life along miles of streams and rivers. Nitrogen from CAFOs enters water bodies not only through surface and groundwater flows, but also through the air in the form of ammonia. Stronger regulations regarding the location and operation of these facilities are critical.

Even at its most intense, however, the problems presented by agriculture can be reversed, if the political will exists to do so. This is not so with urban development. The mistakes made in the next few decades will persist—as will the ecological damage they cause—beyond the end of this century.

Neighborhood Scale

Density

The counterpart to maintaining undeveloped watersheds is focusing development into watersheds already developed at densities adequate to meet regional growth needs. In addition to slowing the spread of development, density increases offer dramatic transportation benefits, with consequent reductions in air and water pollution.

"In addition to slowing the spread of development, density increases offer dramatic transportation benefits, with consequent reductions in air and water pollution."

Studies show that as housing and employment densities rise, the number and length of automobile trips declines. Air pollutants—nitrous oxides, carbon monoxide, and volatile organic compounds—also decrease (Frank, 2000). One study concludes that the number of miles traveled per household falls by 35 percent when residential densities move from two units per acre to ten units per acre (Figure Six). Studies of transit usage establish seven to eight residential units per acre as the minimum housing density necessary to support regular transit service (Pushkarev and Zupan, 1977). This is encouraging because it suggests that regions can achieve reductions in driving, transit-usage increases, and improvements in air and water pollution without moving to substantially different residential housing types. Indeed, some of the most beloved older neighborhoods in the country are "transit-oriented" neighborhoods with roughly ten residential units per net acre.

Yet, urban housing densities have fallen dramatically over the past 30 years. In the

Chesapeake Bay area, for example, the average lot size expanded from 0.18 acres in the 1950s to 0.65 acres in the 1980s (CBP, 1988). Between 1973 and 1995, housing densities in south Florida fell from 2.7 units per acre to 2.4 units per acre (Wallis et al., 2001). There are many reasons for this. First, a significant number of families in the U.S. have moved to large-lot subdivisions in the suburbs, seeking privacy, space, and better schools. This trend was accelerated by federal programs such as the interstate highway system, which allowed long-distance commuting, and home mortgage insurance, the implementation of which favored construction of new single-family homes over rehabilitation of downtown housing.

"... a significant number of families in the U.S. have moved to large-lot subdivisions in the suburbs, seeking privacy, space, and better schools."

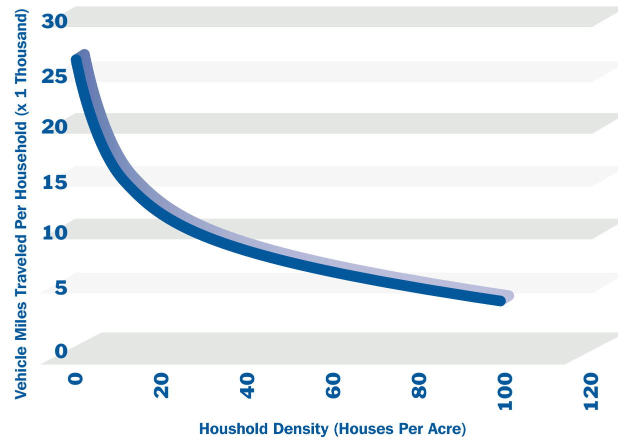
Local governments in suburban areas have amplified these trends by enacting zoning codes that mandate large lots occupied exclusively by single-family houses. Most zoning codes derived from the U. S. Department of Commerce's model Uniform Zoning Code. Developed in the early 1900s, the Uniform Zoning Code was intended to separate residential areas from heavy industrial uses. Finally, public and private disinvestment in cities has resulted in decaying infrastructure and a declining housing stock, thus driving residents from cities to suburban areas. Reversing the trend of declining housing densities will require a concerted effort to rebuild cities and eliminate exclusionary large-lot zoning in the suburbs.

Simply defining the problem has been difficult. While the public associates density with urban problems such as crime and poor schools, it also associates density with suburban ills such as traffic congestion. Indeed, the point has been made that the two things Americans dislike most

Figure Six

Relationship Between Annual Vehicle Miles Driven Per Household and Residential Housing Density

Higher residential housing densities correlate with reduced automobile trips per household, reducing air and water pollution. Increasing densities from two to ten houses per acre can reduce the number of household trips by one-third. Many turn-of-the-century suburbs, with predominantly single-family housing, were built at ten houses per acre. Public parks and other civic spaces in these traditional neighborhoods offer pleasing places for people to walk.



Source: Holtzclaw, 1994.

are sprawl and density. The reason for this apparent paradox is that during the past 50 years urban planning and regulation have focused disproportionately on regulating density, while failing to address other aspects of development, such as street layout, parks, the mixture of uses within a neighborhood, and architecture. Consequently, the common response to new development as "too dense" has become a national reflex action.

There is a great need to explain the benefits of denser communities not only from an environmental perspective but also for the many other advantages such places offer. The best opportunities to do this involve using the examples of real communities with higher housing densities that are widely acknowledged as desirable. There are thousands of examples across the country, from prerevolutionary cities and towns on the East Coast—Annapolis, Boston, and Savannah—that are now major tourist destinations because of their exceptional urban design, to streetcar suburbs like Shaker Heights in Cleveland, to newer West Coast cities such as San Francisco and Monterey. All of these places exhibit patterns of settlement that offer environmental, social, and economic advantages to their citizens.

Figure Seven

Effects of Street Design on Open Space, Vehicle Miles Traveled (VMT), and Other Quality-of-Life Factors

The design of street networks is an important determinant of travel behavior. The connected blocks of traditional street designs (labeled "Traditional Neighborhood" in the diagram below) encourage walking and biking and allow for less congested traffic flow. Higher block densities result in fewer vehicle miles driven and lower emissions of nitrous oxides—a major pollution source in coastal waters. Suburban sprawl (shown in the top half of the diagram) incorporates more pavement per unit, encourages more driving, and offers fewer opportunities for walkers and bicycle riders.

SUBURBAN SPRAWL

TRADITIONAL NEIGHBORHOOD

Source: Duany et al., 2000; Frank and Stone, 2000.

Street Networks

Another aspect of development that has enormous implications for marine protection and for environmental quality, in general, is street layout. Until the end of the 19th century, virtually all cities and towns were built on a rectilinear grid of streets interspersed with parks and other civic spaces. Well-known examples include Savannah, Georgia; Philadelphia, Pennsylvania; and San Francisco, California (Figure Seven).

The rectilinear layout provided many routes to travel from one point to another and minimized the length of each trip. At the low speeds achieved by horses, wagons, and on foot, a grid street system, with its high degree of "connectivity," was a critical aspect of urban travel efficiency in 19th century America.

Initially, the automobile's higher travel speeds freed urban designers from the rigidity of the grid. The Garden City movement in England, which later spread to America, imbedded urban residential settlement in naturalistic surroundings that reflected the rural landscape. These new suburban designs incorporated roads that curved around significant landscape features, or simply meandered to create more interesting travel ways. Blocks became longer and intersections less numerous.

To counter the higher speeds automobiles could reach on these roads, developers terminated residential streets in cul-de-sacs. Branching cul-de-sac designs had swept across the nation by the end of the 20th century. The vast majority of new single-family housing developments in the country now exhibit these layouts.

Replicating these designs across the country has caused a precipitous rise in the length of automobile trips, and a decline in the number of

“Suburban zoning has now become an engine of pollution rather than a shield against it.”

trips made on foot or by bike. In one study, people living in communities built after 1977 took less than one-third as many trips on foot or by bike as those living in communities built before 1947 (Frank, 2000). Over the past 20 years, the number of trips made on foot has declined by 42 percent (STPP, 1999). This, in turn, has caused dramatic increases in traffic congestion and in transportation-related air and water pollution.

Many local governments have begun to promote a return to more functional street systems by increasing block density within new developments and linking new projects to their neighbors. Research shows that higher block densities correlate with shorter trips and lower emissions of nitrous oxides. This is particularly important on the coast, where nitrogen is one of the most damaging contaminants in coastal estuaries (Frank and Stone, 2000). The most serious opponents to these reforms are neighborhood groups who vigorously object to their roads becoming “cut-throughs.” This reaction suggests that rather than attempting to sell these design changes piecemeal, development reforms should be bound into a larger community vision for land-use reform.

Mixed Uses

Conventional zoning separates various land uses from one another (Figure Eight). Originally justified by the need to prevent polluting factories from locating next to houses, zoning has reached an unjustified level of complexity. This is especially true in the assignment of suburban housing densities. Some suburban jurisdictions have as many as ten residential zoning categories, distinguished by the size of the lot and the type of housing.

In addition to separating housing types, zoning separates houses from stores, offices, and schools. Daytime activities are usually grouped along the high-volume roads that emerge to accommodate the morning exodus from residential subdivisions. This rigorous division of uses has contributed to the increase in trips taken by car and to the reduction in trips made on foot. One study on the coast of South Carolina concluded that the percentage of students who walk to schools built before 1983 is four times that of students who walk to those constructed after 1983 (Kouri, 1999).

Neighborhood Scale Summary

Single-use zoning, branching cul-de-sac street systems, and lower housing densities have caused dramatic increases in the length and number of automobile trips. Suburban zoning has now become an engine of pollution rather than a shield against it. Individual neighborhood design reforms—density, street connectivity, and mixed uses—offer significant advantages. However, the research suggests that the best results occur when all of these features are combined in new development—that is, when neighborhoods and regions are laid out in traditional patterns.

Some cities and counties have adopted “Traditional Neighborhood Design” (TND) codes that provide developers the option of building traditional communities. However, the vast majority of jurisdictions in the country still prohibit traditional *development patterns. From minimizing the extent of impervious surfaces to reducing the amount of airborne nitrogen, the benefits of traditional development patterns cannot be overstated.*

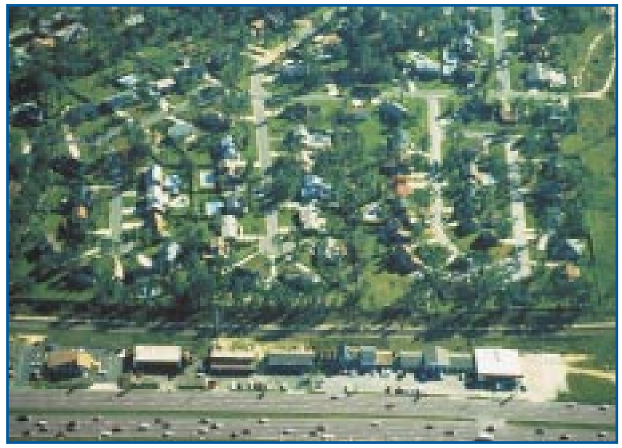
Site Scale

Much work has been done to develop Best Management Practices (BMPs) for development that addresses the quantity and quality of runoff. These practices are implemented at the site or parcel level, and include detention ponds, swales, constructed wetlands, stream buffers and other measures to filter runoff and reestablish natural flow rates.

Site-level practices are essential parts of the overall marine-protection strategy. It is in this arena, through programs like section 6217 of the Coastal Zone Management Act and section 319 of the Clean Water Act, that most of the progress has been made in curbing polluted runoff. However, most regulatory programs focus exclusively on site-level practices, ignoring necessary changes that must take place at the neighborhood and regional scales. This overemphasis has two negative consequences. First, abundant research over the past three decades has proven that site-level practices, in the absence of land-use reforms, cannot protect aquatic ecosystems from decline (Cohn-Lee and Cameron, 1992). The ten-percent rule can be bent, but it cannot be broken. Second, regulatory programs, on occasion, have applied regional scale concepts to the site level. This focus on the wrong scale has the potential to make things worse rather than better.

Figure Eight

Conventional suburban zoning mandates rigid separation between housing, shopping, and jobs, as illustrated by this development near Charleston, South Carolina. Branching street systems terminating in cul-de-sacs eliminate travel choices, ensuring automobile dependency. These development patterns have dramatically increased air pollution, water pollution, and impervious surfaces in the nation's watersheds.



For example, one option for controlling runoff under section 6217 is to impose a maximum percentage of land that should be converted to impervious coverage. When this limit is applied without distinction to heavily developed watersheds and undeveloped watersheds, it has the effect of reducing the number of housing units on each new development site and, over time, reducing development densities across the region. This creates a need for additional roads to connect development that is more spread out, and ultimately increases the total amount of impervious surfaces for a given amount of growth within the watershed. The result runs counter to the principle of focusing development in already-developed watersheds at reasonably high densities.

Box Two

An Integrated Land-Use Agenda

Marine-protection strategies cannot stop with site-level practices at the water's edge. They must reach inland to incorporate regional and neighborhood land-use reforms. These reforms should be imbedded in the comprehensive plans and zoning ordinances of coastal cities, towns, and counties. However, regions must seek to achieve many other goals besides environmental ones, such as the provision of affordable housing, the promotion of economic development, and the protection of historic landscapes. During the regional-planning process, the protection of coastal aquatic ecosystems should be shaped by, and then merged with, these other regional concerns. A regional watershed protection plan should have the following elements:

Regional

1) Characterize the watersheds within the region as developed or undeveloped, identifying the watersheds that are currently less than ten percent impervious and those that are more than ten percent impervious.

2) Assign growth to the developed watersheds first. Then assign any growth that cannot be accommodated in developed watersheds to a limited number of undeveloped watersheds. The watersheds to be developed will be determined by their ecological importance and also by other regional growth considerations, such as the value of terrestrial ecosystems, the economic development potential as determined by proximity to roads and rail lines, and the disposition of landowners in the area toward preservation and development.

3) Adopt policies that maintain impervious surfaces in undeveloped watersheds at less than ten percent. [Private conservation easements, purchase of development rights, infrastructure planning, urban service boundaries, rural zoning (20 to 200 acres per unit, depending on the area), urban growth boundaries]

4) Ensure that local governments zone to provide adequate land for future development within developed or developing watersheds.

Neighborhood

1) Allow residential densities that support transit and reduce vehicle trips per household and minimize land consumption. The minimum density for new development should be seven to ten net units per acre.

2) Require block densities that support walking and reduce the length of vehicle trips. Cities that support walking and transit often have more than 100 blocks per square mile.

3) Connect the street network by requiring subdivision road systems to link with adjacent subdivisions.

4) Integrate houses with stores, civic buildings, neighborhood recreational facilities, and other daily or weekly destinations.

5) Incorporate pedestrian and bike facilities into new development and ensure these systems provide for interneighborhood travel.

6) Encourage and require other design features and public facilities that accommodate and support walking by creating neighborhoods with a pleasing scale and appearance. (e.g., short front-yard setbacks, neighborhood parks, alleys, and architectural and material quality)

Site

1) Require the most effective structural stormwater practices to be applied, especially focusing on hot spots such as high-volume streets, gas stations, and parking lots.

2) Establish buffers and setbacks that are appropriate for the area to be developed—more extensive in undeveloped watersheds than in developed watersheds. In developed watersheds, buffers and setbacks should be reconciled to other urban design needs such as density and a connected street network.

3) Educate homeowners about their responsibility in watershed management, such as buffer and yard maintenance, proper disposal of oil and other toxic materials, and the impacts of excessive automobile use.

V. Implementation Measures

The politics of growth management are complex and controversial, so it is not surprising that the past 30 years of work to protect marine ecosystems have focused on site-level practices rather than broad-based land-use reforms. However, the evidence of ecosystem damage and its relationship to coastal development is overwhelming. It is virtually certain that unless development patterns change, the next 25 years of coastal growth will precipitate severe and irreversible declines in our estuaries and nearshore waters. If the U.S. is to adopt land-use reforms that will protect these systems, we must first understand the limitations in the present systems of planning and regulation. Each level of governance—local, metropolitan, state, and federal—has an essential role to play. No single level can solve the coastal zone management problem alone.

Local Government

Direct, but Fragmented Authority

Land-use policy has always been the purview of the states, and virtually every state has delegated most of that power to its counties, cities, and townships. Localities approve almost every aspect of new development, including location, density, and street design. For the purposes of growth management, local governments are where the action is, and where it will likely remain.

The problem with implementing local growth management policies that protect marine ecosystems, though, is twofold. First, in spite of the fact that local governments make the most important decisions about growth of any level of government, most of them do not understand the implications of their decisions for the environment. Their lack of attention to environmental protection has been reinforced by the fact that states have been officially empowered with environmental protection duties. A concerted education campaign targeted at localities and their elected representatives can help inspire and focus local government action.

The second problem is that metropolitan regions are usually composed of dozens of local governments operating without any regional planning framework. Thus, enlightened city or county plans can be undercut by a lack of planning in neighboring localities. Localities are often discouraged from adopting regulations that are substantially stronger or different from their neighbors for fear of losing what they perceive to be lucrative new development. Still, local governments are largely entrusted with the power to implement land-use decisions that can either protect or destroy marine ecosystems and other environmental resources. A successful coastal protection strategy must ultimately be translated into action at the local level.

"... transportation efficiency has declined steadily over the past three decades, as sprawl has accelerated."

Metropolitan Regions

The Right Scale, the Wrong Structure

Metropolitan regions are the organic units of settlement in America. It is at this level that major planning decisions about growth, transportation, housing, and rural land preservation should be made and coordinated among the constituent localities. A few metropolitan areas, notably Portland, Oregon, and Minneapolis, Minnesota, have regional governments with the power to make land-use decisions. However, most metropolitan areas have no such authority. Some of the largest population centers, such as New York and Washington, D.C., cross state boundaries, making joint planning extraordinarily difficult.

In spite of the obvious link between land-use patterns and transportation efficiency, most regions coordinate only on large-scale transportation projects that receive federal funding, leaving other transportation and land-use actions exclusively to local governments. As a result, transportation efficiency has declined steadily over the past three decades, as sprawl has accelerated. However, federal transportation planning requirements that enable inter-jurisdictional cooperation demonstrate the potential for regional cooperation. It should be possible, with state and federal involvement, to improve this model for transportation and to extend it to address other planning needs, including watershed protection.

State Government

Permitting Could Evolve into Planning

The states have traditionally served as environmental regulators, either implementing federal programs such as the water-pollution-control permit system under the Clean Water Act, or developing their own programs under the Coastal Zone Management Act. However, state agencies have typically steered away from adopting policies that appear to preempt local land-use authority. Although some coastal zone programs include a link to land-use plans, in most cases that link is timid and has little real impact on local decisions. Consequently, rather than promoting land-use solutions to coastal environmental problems, states have stuck to the business of permitting projects, such as docks, marinas, and beachfront erosion-control structures, within "critical areas" of the coastal zone.

Mechanisms such as National Estuary Program (NEP) designations under the federal Clean Water Act and Special Area Management Plans (SAMP) under the Coastal Zone Management Act have made some progress in bringing local planners together with state regulators. However, here, too, participants usually stake out familiar territories and obtain federal funding to do what they have always done, only more vigorously. Cross-disciplinary work that links regional planning to ecosystem health has been rare. The general lack of success of these programs points out that federal directives without incentives, enforcement, or measurable standards of performance are unlikely to be effective.

Driven by concerns other than coastal ecosystem health, states have begun to play a larger role in growth management. For example, Maryland recently passed "smart growth" legislation designed to direct growth into already-developed areas and preserve rural land uses. Ten other states in the country have also adopted growth management legislation, beginning with Oregon's statewide land planning act in 1973. Some states, notably Maryland and California, have adopted programs specifically dealing with land use in coastal areas. Maryland's Critical Area Program, passed in 1984, identified undeveloped coastal areas and imposed low-development densities and streamside buffers within one thousand feet of the Chesapeake Bay and its tributaries.

State growth management goals usually include environmental protection but rarely reach the level of specificity necessary to ensure preservation of coastal ecosystems. Integrating watershed strategies into existing and emerging state growth management programs offers great promise for the cause of marine protection.

Federal Government

No Direct Land-Use Role, but Powerful Linkages

The authority to make land-use decisions, and thereby protect marine ecosystems, clearly rests with the states and their localities. Marine-protection advocates can accomplish a great deal by promoting watershed planning, better infrastructure planning, and zoning reforms at the local and regional levels, and by participating in the movement for state growth-management legislation.

However, the need for reform is urgent. In many states and localities, especially high-biodiversity parts of the country like the Southeast, this process could take decades. Local governments are not likely to produce watershed plans of their own accord, nor are they likely to coordinate this planning with neighboring jurisdictions.

"Local governments are not likely to produce watershed plans of their own accord, nor are they likely to coordinate this planning with neighboring jurisdictions."

The nation faced a similar challenge in the late 1960s. Few states had the political will or technical capacity to control pollution discharges to water and air. Federal legislation provided the legal framework and technical support to undertake that challenge. If the country is to successfully implement the land-use reforms necessary to protect aquatic ecosystems, the federal government must again use its leverage as regulator and funding allocator to help facilitate change.

Necessary federal actions fall into three categories: providing educational and technical assistance for regional planning, linking watershed planning with existing federal regulatory and funding programs, and developing quantifiable standards for protecting ecosystem health.

Educational and Technical Assistance

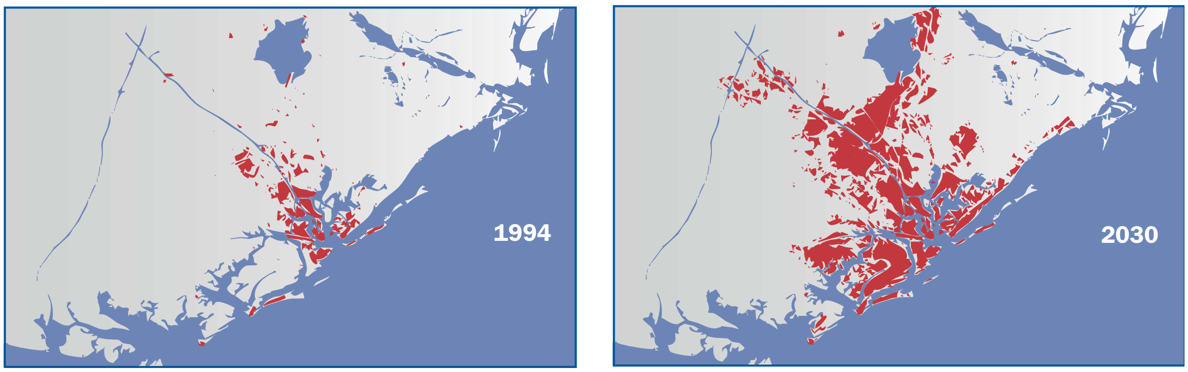
Localities and metropolitan regions must first understand their current growth patterns and competently assess alternatives to conventional sprawl. It is now possible to analyze various land-use choices using Geographic Information

Figure Nine

Key to the Future

Geographic Information Systems (GIS) technology has recently made it possible to graphically depict the expansion of metropolitan areas. It is also possible to combine these mapping tools with predictive models to illustrate the extent of future urban expansion. Clemson University's Strom Thurmond Institute developed such a model for the Charleston metropolitan region. The results suggest that if current land development trends continue, the Charleston area will grow from its 1994 size of 165,000 acres to two-and-a-half times that size by the year 2030. Charleston will cover 550,000 acres—an area larger than the metropolitan area of Charlotte, North Carolina. A comparatively modest 50 percent increase in population will drive this expansion.

Charleston Metropolitan Area



Source: Strom Thurmond Institute, Clemson University.

Systems (GIS) technology. This is called "growth scenario modeling." GIS technology can characterize land-use options visually and quantitatively over long periods. Consequently, they are uniquely valuable for communities faced with important land-use decisions. These models should be made available to citizens and governments to analyze the long-term implications of land-use decisions. During the preparation of this report, the author could locate only five metropolitan regions in the coastal zone that had digitized images of regional growth trends. Only two regions had used those images to project future land-use patterns.

Funding should be made available to develop and test these growth scenario models in selected locations along the coast and to provide this technology to metropolitan areas around the country. Models of increasing complexity can be created that characterize land-use impacts to air and water quality, terrestrial and aquatic habitats, and other regional resources. Once basic land-development data is assembled in GIS format, additional information layers are often relatively easy to produce. Growth models can be as valuable to citizens and activists as they are to local planning departments. For that reason, it is important to ensure that images and software are widely distributed and easy to use.

Decision-makers also need to understand the human aspects of alternative growth patterns. Presently, many local representatives and most neighborhood groups believe that increased housing densities create undesirable living conditions. Yet there are thousands of communities across the country built at far higher densities than conventional suburban development that are widely acclaimed and highly valued. Educational efforts should focus on revealing how these places function and what planning and zoning changes are necessary to re-create them. Images and quantitative analyses of key places around the country could be compiled and made available to counter the destructive bias against density.

Congress could provide funds for regional land-use analysis during the reauthorization of the Coastal Zone Management Act. Coastal zone agencies, in conjunction with regional transportation planning agencies or councils of governments, could coordinate the development of models and images to analyze growth and transportation options. Regardless of how funding is allocated, model development must be done in conjunction with local stakeholders and land-use decision-makers. Otherwise, funds will be wasted on products that are not relevant to the scale and type of decision localities must make about land use.

Linking Watershed Planning with Existing Programs

Many federal programs facilitate or approve development that damages coastal ecosystems. Permitting and funding under these programs should encourage growth patterns that minimize land conversion and provide alternatives to automobile travel, protecting coastal ecosystems. This can be accomplished by requiring coastal regions to develop watershed protection plans and then ensuring that federal projects and permits are consistent with those plans.

Federal Transportation Funding

Federal transportation funding is perhaps the most important determinant of regional growth patterns. Regions that fail to meet federal Clean Air Act standards must demonstrate that they have taken steps to reduce overall driving before they add new lane capacity. Not only is this Clean Air Act "consistency" requirement a valuable exercise for air-quality protection, it has important water quality benefits as well. Federal consistency could be expanded to require the development of regional land-use plans that protect watersheds.

Under the reauthorization of the Transportation Equity Act for the 21st Century (TEA-21), it is possible to shift funding from highway construction to land-use planning that promotes better travel patterns. Both the Atlanta metropolitan region and the San Francisco Bay Area have used federal funds to plan transit-oriented developments and mixed-use, pedestrian-friendly neighborhoods (Steuteville, 2001). Reauthorization of TEA-21 represents an extraordinary opportunity to expand the use of federal funds for land-use analysis and planning.

The prospect of linking transportation funding with land-use planning already has a strong constituency among local governments. A study conducted by the U. S. General Accounting Office found that half of all cities

"The prospect of linking transportation funding with land-use planning already has a strong constituency among local governments."

and counties surveyed strongly support a federal requirement that road and highway projects be linked with local land-use plans (U.S. GAO, 2000).

"Many states are finding that urban and suburban runoff is reducing the ability of their rivers to absorb pollution without becoming degraded."

Clean Water Programs

Watershed planning could also be included in federal regulatory programs under the Clean Water Act. Presently, states are required to develop Total Maximum Daily Loads (TMDLs) for their rivers and streams. TMDLs determine how much pollution a body of water can accept without becoming degraded. States then use TMDLs to allocate pollution permits among dischargers such as industries and municipal sewer authorities. Many states are finding that urban and suburban runoff is reducing the ability of their rivers to absorb pollution without becoming degraded. This means that runoff from new development is progressively diminishing the share of pollution each industry can discharge.

Part of the TMDL process should include developing regional watershed-protection plans that minimize pollution from new growth. Local governments would have to adhere to these pollution-minimizing land-use plans, just as industries must abide by their pollution permits. This would properly shift some of the burden of protecting water quality from the shoulders of regulated dischargers to those of local governments, whose land-use decisions are the most important determinants of regional water quality and ecosystem health. For that reason, industry and municipal sewer authorities are likely to support such a planning requirement.

Other Federal Funding

Federal infrastructure funds provided by agencies such as the EPA and the Department of Agriculture could be made contingent on the preparation of regional watershed-protection plans. Wastewater facilities funding, for example, should be contingent on preparation of regional watershed plans. This could prevent the expenditure of federal funds on inappropriate, sprawl-inducing sewerage and waterlines. Reauthorization of the Farm Bill provides yet another opportunity to link the receipt of federal funds, under initiatives like the Conservation Reserve Program (CRP), with the development of regional watershed-protection plans.

National Environmental Policy Act

Another vehicle to encourage land-use decisions that protect aquatic ecosystems is the National Environmental Policy Act (NEPA). Presently, major projects that are federally funded or require federal permits must be analyzed in light of "practicable alternatives." An agency that proposes building a new road that destroys wetlands, for example, must analyze other routes that would reduce wetland impacts. The NEPA alternatives analysis provision should be rewritten to explicitly require that alternative land-use scenarios be analyzed in evaluating damage to aquatic and terrestrial ecosystems.

Federal Government Summary

In summary, all federal programs that affect coastal ecosystems should be linked to regional planning for watershed protection. Permitting and funding decisions should be consistent with these plans. These changes would not only result in greater protection for aquatic systems, they would also help protect the nation's massive investment in pollution-control technology and other clean-water strategies.

Developing Quantifiable Performance Standards

To achieve the goal of protecting coastal waters, watershed planning must be measured against clear, quantifiable standards of ecosystem health. However, ecosystems are complex, difficult to assess, and variable from place to place and region to region. Consequently, an effective evaluation system should combine ultimate measures of health, such as species diversity, with proximate measures of impacts, such as vehicle miles traveled (VMT).

Ultimate measures of ecosystem health include biological diversity, the physical structure and habitat quality of streams and rivers, and pollutant concentrations. Conventional water-quality standards, such as dissolved oxygen and fecal coliform levels, are important benchmarks of ecosystem health. The availability of this information varies dramatically across the country, with the most comprehensive data present in places like the Chesapeake Bay and San Francisco Bay, but much sparser information available in less heavily developed regions.

Proximate measures of impacts can more easily be tracked in every region in the coastal zone. Such measures include vehicle miles traveled (VMT), which is directly linked to atmospheric deposition of nitrogen and other pollutants, impervious surface coverage, which is linked to virtually every aquatic ecosystem stress, and the regional rate of population growth compared to land consumption. Some regions have already begun to establish these types of growth management measures. The Chesapeake Bay Agreement, covering the states of Virginia, Maryland, and Pennsylvania, sets the goal of reducing the rate of land consumption by 30 percent and permanently preserving 20 percent of the land in the bay's watersheds over the next 10 years.

Neighborhood design determines travel behavior and drives regional land consumption. Consequently, it is every bit as important to ecosystem health as regional land-consumption measures. However, this aspect of regional growth has been completely absent from the discussion of environmental goal setting. Neighborhood design elements with demonstrably strong relationships to environmental impacts include the density of housing and employment, the block density or "connectivity" of the street system, and the extent of land-use mixing. These measures should be accorded equal weight with regional-scale indices such as the rate of land consumption.

Regions should be directed to select appropriate measures of performance from each of these categories in developing watershed-protec-

"To achieve the goal of protecting coastal waters, watershed planning must be measured against clear, quantifiable standards of ecosystem health."

tion measures. Coastal zone managers should also continue to assess how accurately these measures predict environmental health. Rapid advances in mapping and modeling technologies over the coming years will make it much easier to evaluate how successfully regional planning efforts protect aquatic ecosystems.

"America's oceans and estuaries are international resources, yet their fates lie in the hands of thousands of individual towns, cities, and counties throughout the coastal zone."

Conclusion

The coast faces a daunting array of threats in the coming decades—global climate change, invasive species, overfishing, and industrial pollution. None of these threats should go unanswered, especially since some of the damage is reversible if it is addressed in time. However, the wholesale transformation of coastal watersheds—from living communities of soil and plants to cities of concrete and asphalt—is irreversible. For that reason, land-use reform must be at the forefront of the coastal-protection agenda.

A national agenda to protect coastal ecosystems must bridge the gap between traditional environmental protection measures and local land-use practices. No level of government—local, metropolitan, state, or federal—can implement such an agenda unilaterally. Instead, each must be responsible for its particular part of the solution. The centerpieces of the agenda are regional watershed-protection plans, facilitated and encouraged at the federal and state level, and developed and implemented at the regional and local levels.

Underlying this effort must be a broad public education campaign (Box Three). Unlike many environmental issues, land-use reform is too complex a message to capture on a bumper sticker. It touches too many facets of life to be extracted as a simple maxim like "Reduce, Reuse, Recycle." Fortunately, new communications and mapping technologies can make land-use issues clearer and more compelling than ever before.

America's oceans and estuaries are international resources, yet their fates lie in the hands of thousands of individual towns, cities, and counties throughout the coastal zone. The plight of these natural systems epitomizes the plight of major ecosystems worldwide, where the structures of authority are dwarfed by the enormous implications of the decisions made. Reforming coastal development patterns will be more complex and politically charged than previous environmental-protection campaigns, but it also offers the opportunity for broad and lasting political alliances. Our failure to act now on land-use reform will consign many of the coast's aquatic ecosystems to severe and irreversible decline within the next 25 years.

Box Three

An Education Campaign

Land-use reform can capture the public's imagination as powerfully as any environmental issue. It deals with such basic questions as where people live, how they travel, when they interact with their neighbors, and how they spend their leisure time. An education campaign has the potential to be profoundly successful if it considers the particular challenges this issue presents and harnesses its unique strengths.

First, land use is visual. An education campaign should rely heavily on the variety of visual technologies now available—geographic information systems (GIS), computer animation, satellite imagery, and digital photography. Satellite imagery of metropolitan regions can convey historical and future growth trends. Computer animation can demonstrate how different policies will change the function and feel of neighborhoods. Video clips can explain how various land-use choices affect families in their daily lives. Computer-presentation technology can make these images available to civic groups and decision-making bodies around the country. Computer presentations could be developed and made available to activists across the country on the Internet or on CDs.

Second, land use is local. Visual communications material should be tailored for local use. Digital cameras make it easy to insert local material in stock presentations designed to convey general principles. Mapping and growth projection methodologies can be transferred from one region to the next across the nation. One particularly promising opportunity is to establish regional "learning centers" at key locations around the country. These places would be visited by millions of people annually. They would house exhibits illuminating the relationships between regional growth patterns and estuarine health, between travel patterns and global warming, and between sea-level rise and beach erosion. These centers would present the reforms necessary to avert or attenuate these threats.

Third, land use is multidisciplinary. For this reason, coalitions of various interest groups—locally and nationally—are both necessary and desirable. Few issues offer the potential to blend diverse advocacy agendas—such as affordable housing, transportation reform, and marine protection—as effectively as land use. The leading coalitions working for land-use reform are the Congress for the New Urbanism, Smart Growth America, the Smart Growth Network, and the Growth Management Leadership Alliance. These coalitions and their members have extensive resources—research, images, strategies—and tremendous outreach potential to millions of people within their constituencies.

Ultimately, land-use education is a challenge of making linkages, between causes and effects that appear unrelated, between constituencies that believe they have little in common, and between places that seem to be far apart. Only in the last decade, have the tools been widely available to make those links. These new tools offer the prospect to change the way metropolitan regions think about themselves and relate to their environment.

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The Pew Oceans Commission is an independent group of American leaders conducting a national dialogue on the policies needed to restore and protect living marine resources in U.S. waters. After reviewing the best scientific information available, the Commission will make its formal recommendations in a report to Congress and the nation in 2002.

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