Chapter 2

The State of the Estuary

Brown pelican (Pelecanus occidentalis).

CHAPTER TWO: THE STATE OF THE ESTUARY

Los Corozos Lagoon

AN ESTUARY IS A COASTAL AREA where fresh water flowing from rivers and streams mixes with salt water in the ocean, bays, lagoons, and channels. The San Juan Bay Estuary (SJBE) system includes San Juan Bay, the Condado Lagoon, the San José Lagoon, Los Corozos Lagoon, La Torrecilla Lagoon, and the Piñones Lagoon, as well as the interconnecting Martín Peña and San Antonio Channels and the Suárez Canal. (See Figure 2.) Fresh water flows into the system from the creeks and rivers in the watershed, including the Puerto Nuevo River, Juan Méndez Creek, San Antón Creek, Blasina Creek, and the Malaria Canal. During extreme flood events, fresh water is also received from the Río Grande de Loíza. Ocean water enters the system through three openings: Boca del Morro, El Boquerón at the Condado Lagoon, and Boca de Cangrejos.

San Juan Bay is the most recognized component of the entire system. The bay has approximately 6.5 miles (10.5 km) of coastline and is highly developed. San Juan Bay was described by early settlers as one of the most magnificent harbors of the New World. Today, the area surrounding the harbor is highly urbanized, with office buildings, residential areas, parks and recreation areas, cargo and cruise line terminals, and an extensive and sophisticated transportation network.

Figure 2. SJBE Program study area.

San Juan Bay is connected to the Atlantic Ocean by the Boca del Morro and to the Condado Lagoon by the **San Antonio Channel**. The San Antonio Channel is 1.2 miles (2 km) long and is fringed by a number of port-related facilities as well as two marinas on the eastern end.

The **Condado Lagoon** is approximately 102 acres (39.5 ha) in area and contains a small sandy beach used by thousands of tourists and locals throughout the year. It has an outlet to the Atlantic Ocean in the area known as El Boquerón, to the east of the San Gerónimo Fort. The lagoon is surrounded by upscale residential buildings and hotels along its northern shore and is frequently used for passive aquatic sports such as windsurfing, rowing, sailing, and swimming. The Condado Lagoon is one of the most diverse areas within the SJBE system in terms of its marine flora and fauna.

The **Martín Peña Channel** measures approximately 3.75 miles (6 km) in length and ranges in width from 6 feet (2 m) to over 400 feet (122 m). The channel is very shallow, with an average depth of 4 feet (1.2 m). Martín Peña Channel has been impacted by intensive residential development and related activities for many decades. The western half of the channel was dredged to approximately 10 feet (3 m), is surrounded by mangroves, and has a concrete boardwalk along one of its banks. Along the eastern segment of the channel, residents have used refuse and construction debris for decades as fill material at the edge of the channel. Along the banks, mangroves and other vegetation can be found interspersed with substandard dwellings. The Martín Peña Channel links San Juan Bay with the San José Lagoon.

The **San José Lagoon** is located near the center of the estuary system. The lagoon is divided into two segments: **Los Corozos Lagoon** to the northwest and San José Lagoon to the southeast. These waterbodies have a surface area of approximately 1,129 acres (457 ha). Because they have no direct outlets to the Atlantic Ocean, these two lagoons are the least influenced by the tide. Most of the shoreline of these two lagoons is forested with mangroves, but the western and southwestern banks have been filled for the construction of housing. Water exchange between the San José

Lagoon and San Juan Bay is limited by sedimentation and the accumulation of debris in the Martín Peña Channel. The **Suárez Canal** is located on the eastern part of the San José Lagoon. This roughly 2.4-mile (3.9 km) long forested canal links the San José Lagoon to La Torrecilla Lagoon.

La Torrecilla Lagoon is connected to the Atlantic Ocean by a narrow outlet at Boca de Cangrejos. This lagoon has a surface area of 608 acres (246 ha) and is mostly surrounded by mangroves.

The **Piñones Lagoon** is located to the east of La Torrecilla Lagoon and is surrounded by the Piñones State Forest Nature Reserve. The Piñones and La Torrecilla Lagoons, together with the Vacía Talega - Torrecilla Alta area, contain approximately 5,493 acres (2,223 ha) of mangroves and 5,079 acres (2,056 ha) of herbaceous wetlands.

As stated in the San Juan Bay Estuarine System Nomination Package for the National Estuary Program, systems associated with the estuary but not necessarily located within the transitional mixing zone characteristic of estuaries are included within the geographic scope of the SJBE system. These include sandy beaches, natural outcroppings, coral communities, cemented sand dunes, and their associated fauna and flora.

The SJBE system is also defined by small isolated creeks and canals as well as upland areas that drain into the estuary waters described above. The watershed or drainage basin is relatively small (< 97 square miles (251 km^2). It extends above a broad, flat coastal plain and consists of 83 square miles (215 km^2) of land and 14 square miles (36 km^2) of water. Eleven square miles, (28 km^2) or about 12% of the basin, are covered with fill.

The estuary basin is almost completely urbanized. Parts of eight municipalities join to form the estuary's watershed: Toa Baja, Cataño, Bayamón, San Juan, Guaynabo, Carolina, Loíza, and Trujillo Alto. Land uses and activities in these areas are closely linked to water quality impacts and the degradation of habitat in the estuary.

Red Mangrove (Rhizophora mangle).

Climate

Average monthly temperatures along the SJBE coastline range from a high of 81° F (27° C) in August to a low of 73° F (23° C) in January/February. Mean annual rainfall ranges from 59 inches (1,500 mm) near the ocean to 83 inches (2,100 mm) in the uplands at the southern boundary of the drainage basin. The majority of the rain falls from July through September and is associated with the easterly storm fronts passing through the region four to six times per month. Another peak rainfall typically occurs in May (Webb and Gómez-Gómez, 1998). From May through October, tropical waves, some of which develop into hurricanes, commonly pass through the region and deliver torrential rains.

Land Use and Population

San Juan metropolitan area.

The majority of the land in the SJBE drainage area has been developed for urban and residential uses. Housing and commercial development have replaced extensive areas of pasture and forest in the uplands of the Rio Piedras watershed over the last two decades. Land uses in the SJBE are shown in Figure 3.

According to CSA Architects and Engineers/ Weston, Inc., (1999[b]), land uses within the SJBE watershed in 1995 consisted of:

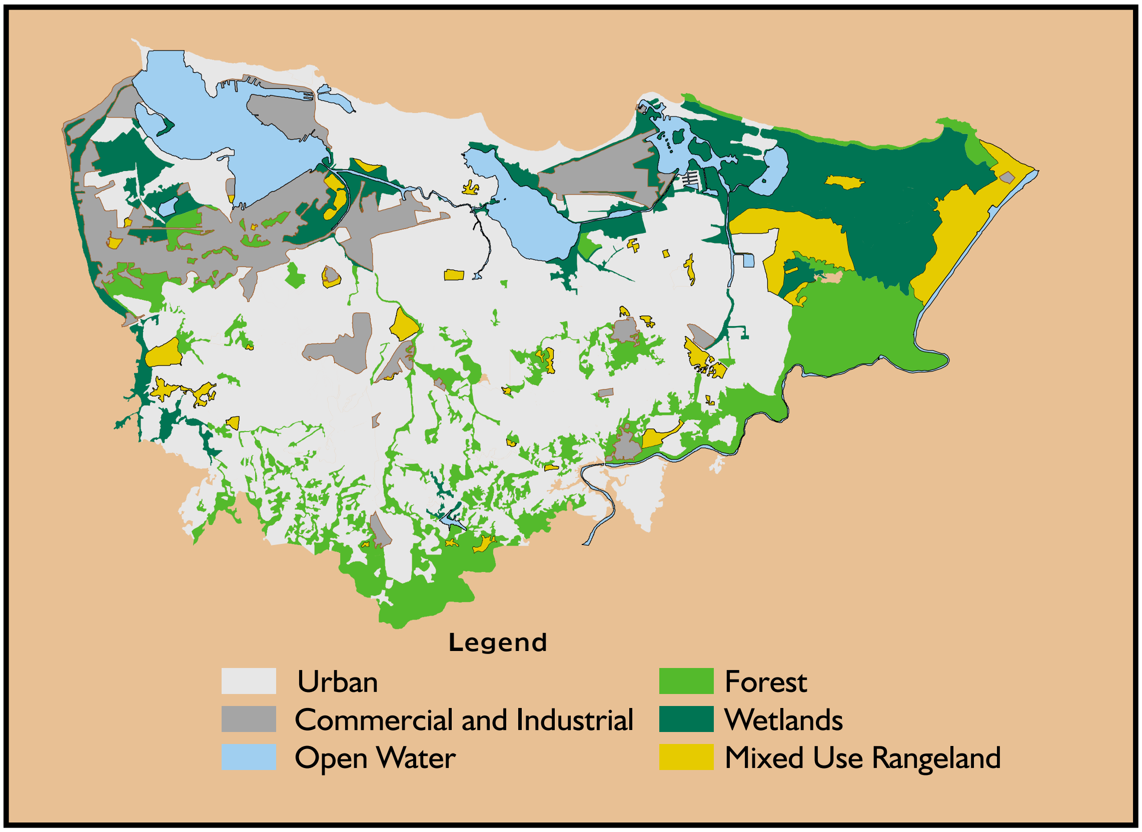
• Urban areas	67.0%
• Surface water	10.9%
• Forest, wetlands, and green areas	21.7%
• Other (including transitional areas)	0.4%

Approximately 622,000 residents live within the SJBE drainage basin, based on the 1990 Census (Webb and Gómez-Gómez, 1998). Population densities range from a low of 244 persons per square mile (94 persons per square kilometer) in Barrio Torrecilla Baja, in the area of the Piñones State Forest, to 21,500 persons per square mile (8,300 persons per square kilometer) in Barrio Hato Rey Central where high-rise condominiums are prevalent. The average population density is 8,300 persons per square mile (3,215 persons per square kilometer).

> *Between 1964 and 1990, car ownership in the 5 central municipalities of San Juan increased by 287%. At about 161 vehicles per mile of paved road (100 vehicles per kilometer), the density of vehicles in the San Juan area is already 3 times higher than the U.S. mainland and is among the highest of all metropolitan areas in the world.*

Between 1964 and 1990, the population in the San Juan Metropolitan Area, within which the SJBE is located, increased by 87 percent, from 695,000 to 1.3 million. Population is projected to increase by another 20 percent by the year 2010 (based on the 1990 Census).

Figure 3. Land uses in the SJBE Program area. (Source: CSA Architects and Engineers/ Weston, Inc., 1999[b].)



Economy

Puerto Rico is the most industrialized island in the Caribbean. The manufacture and export of goods such as pharmaceuticals, high technology equipment, and rum play a key role in the economy. The gross domestic product (GDP) of Puerto Rico exceeds $48 million per year; per capita GDP is $12,212, the highest in Latin America. The service sector, including tourism, accounts for 37 percent of the GDP (Puerto Rico Tourism Company, www.prtourism.com).

Functions of the Estuary System

The SJBE system is an irreplaceable natural, recreational, and commercial resource for Puerto Rico's residents and visitors. A wide variety of living resources find food and shelter in estuary waters and associated wetlands, including marine mammals, birds, fish, shellfish, reptiles, and plants. The system's mangroves and coral communities offer especially important breeding, nursery, and sheltering habitats for fish, shellfish, and other marine biota.

Healthy estuaries and their associated marshes and other wetlands act as sponges, absorbing stormwater runoff, which protects developed areas from flooding. Marsh grass and other vegetation slow the flow of stormwater and trap and filter sediments, nutrients, and pollutants. Estuaries can also provide natural buffers between developed land and the sea. They help to protect the shoreline from storm surges and erosion.

The natural beauty and ecological diversity of the estuary support tourism and water-based recreational activities which generate significant revenue. The SJBE is also valued for its commercial port, cruise ship port-of-call, and historic sites.

All of these benefits are being provided by the estuary and its natural communities without any direct investment by society. As the population grows and the demands imposed on the natural resources increase, so too does the importance of protecting these resources for their natural, economic, and aesthetic values. The health and balanced use of the SJBE system is critical to the survival of the fisheries and plants and wildlife, as well as the livelihoods of the citizens.

Water & Sediment Quality

Port facilities at Canal San Antonio.

The water and sediment quality of the SJBE system is closely related to both the natural characteristics of the estuary system, such as the tides, geology, and the currents in the lagoons and nearshore marine waters, and human impacts, such as dredging and filling, development of natural areas, and domestic and industrial discharges (Webb and Gómez-Gómez, 1998).

San Juan Bay is the focal point for most of the past and present development within the San Juan metropolitan area, and the bay's drainage basin has been almost completely urbanized. The intensity and diversity of human activities taking place within the metropolitan area have influenced the water and sediment quality of the estuary in many ways, impairing in many instances its functions and values.

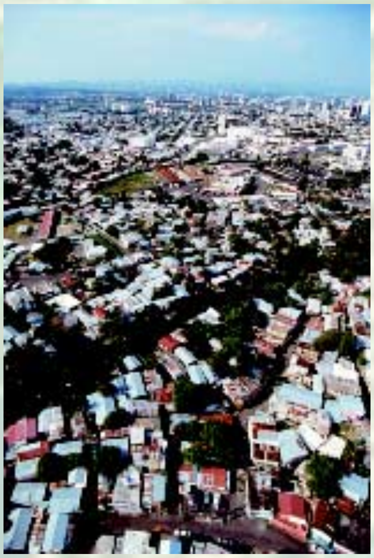
Brown pelican (Pelecanus occidentalis).
Courtesy of USFWS.

Highlights of the San Juan Bay Estuary

The SJBE provides a home for over 160 bird species, 19 reptile/amphibian species, and 124 fish species including 18 sport fish species, and approximately 300 wetland plant species.

Some endangered, threatened, endemic, and/or rare species in the estuary's watershed and associated areas include the Brown Pelican, the Peregrine Falcon, the Roseate Tern, the Yellow-shouldered Blackbird, the Leatherback Turtle, the Green Turtle, the Hawksbill Turtle, the West Indian Manatee, and 17 plant species.

West Indian Manatee. Courtesy of USGS.



Urban development encroaching the Martín Peña Channel.

Approximately 622,000 people live within the SJBE watershed (based on 1990 census), and the average population density is 8,327 persons per square mile (3,215 persons/square kilometer).

Red mangrove (Rhizophora mangle).

The Piñones State Forest Nature Reserve, located in the easternmost section of the SJBE, contains the largest protected mangrove forest in Puerto Rico. This forest, along with other mangrove areas in the estuary, comprises approximately 7,512 acres (3,040 ha) or 33 percent of the total mangrove acreage on the island.

In 1995, over 324,500 pounds of finfish were landed in four municipalities within the SJBE (Cataño, San Juan, Loíza, and Carolina). The majority of these species are estuary-dependent in their juvenile stage.

San Juan Bay is the 17th largest port facility in the world. It is the second busiest container port among ports on the east coast of the United States. San Juan's shipping container volume is greater than the combined cargo volume of Guam, Alaska, and the Hawaiian Islands. The port is quickly growing, as major improvements to the existing navigational channels are currently underway.

Sport fishing species, snook (Centropomus undecimalis) *and tarpon* (Megalops atlanticus). *Courtesy of DNER Fisheries Laboratory.*

Cruise ship entering San Juan Bay.

The San Juan area is the largest tourist destination on the Island. In 1997, approximately 1.1 million cruise ship passengers arrived in the port of San Juan, and 9.8 million travelers used the Luis Muñoz Marín International Airport.

Water and sediment quality within the SJBE is affected by both point sources and nonpoint sources of pollution. In general, **point source pollution** comes from an easily identifiable point or place of discharge and includes permitted discharges from facilities such as sewage treatment plants and industrial sites. According to the Puerto Rico Water Quality Standards and the definition of point sources, points of discharge include pipes, ditches, channels, tunnels, conduits, wells, discrete fissures, containers, rolling stock, homes, cafeterias, concentrated animal feeding operations, and vessels or other floating craft from which pollutants are or may be discharged. Point source pollution contributes heavy metals, nutrients, and toxic organic chemicals, and heated effluents to the SJBE system. Point source discharges "tend to be continuous, with little variability over time, and often they can be monitored by measuring discharges and chemical concentrations periodically at a single place" (Carpenter, *et al.*, 1998; EQB, 1990). Consequently, point sources are relatively simple to monitor and regulate and can often be controlled by treatment or reduction at the source.

Nonpoint source pollution comes from different, diffuse, and often mobile sources throughout the estuary that are generated by a variety of land uses and everyday activities. In general, the primary sources of nonpoint pollution include runoff from agricultural areas, urban stormwater runoff from residential and industrial areas, seepage from sanitary landfills and on-site septic systems, and releases from vessels (e.g., minor oil spills) (National Safety Council, 1998). Agricultural land uses within the SJBE watershed are minimal; therefore runoff from these areas is not a significant contributor of pollutants to the SJBE (CSA Architects and Engineers/Weston, Inc., 1999[b]). Stormwater runoff carries many pollutants into the estuary system, including oil, gasoline, grease, pesticides, fertilizers, and metals (primarily copper, cadmium, zinc, lead, and nickel). Sanitary landfills, in general, are a significant source of metals, nutrients, pesticides, pathogens, and synthetic organic compounds. Leaching on-site septic systems can contribute excessive nutrients to the estuary system, adding to eutrophication problems. Because nonpoint source pollution cannot be traced to any single source, it is much more difficult to measure and regulate (Carpenter, *et al.*, 1998).

Eutrophication

The most common and widespread impairments to the SJBE waters are eutrophication and fecal contamination by excessive inputs of nutrients, caused mostly by sewage discharges from a variety of sources (Webb and Gómez-Gómez, 1998). Eutrophication refers to the enrichment or accumulation of nutrients above natural levels in surface waters. While nutrients are required for plant and animal growth, levels that are too low or too high can result in unproductive or over productive habitats (USGS, 1996). For example, an excessive amount of nutrients entering a water body typically fosters the growth of microscopic algae. During daylight hours, oxygen is normally produced up to super saturation levels by the abundant algae populations. However, with the onset of dusk, algae photosynthesis slows and oxygen demand increases. By early morning, it is not uncommon to find depressed dissolved oxygen (DO) concentrations that make the water environment incapable of sustaining many aquatic organisms. This variation in DO concentrations is typically found in the San José and Los Corozos Lagoons (Webb and Gómez-Gómez, 1998).

The quality of water and sediments in the SJBE system is also affected by erosion and sedimentation, thermal pollution, hydrologic changes caused by channelization and draining of wetlands and other waterworks, construction of docks and boating infrastructure, and the operation of watercraft, especially in shallow waters. As a result, the waterbodies of the SJBE are only capable of sustaining limited uses. Pollution sources and their impacts to water and sediment quality and human health are discussed in the following sections and are addressed in the Water and Sediment Quality Action Plan in Chapter 3.

Water Quality Standards within the SJBE

The Puerto Rico Environmental Quality Board (EQB), through the promulgation of the Puerto Rico Water Quality Standards Regulation, has designated uses, such as drinking, irrigation, fishing, swimming, or recreation, for which water quality shall be maintained and protected and has prescribed the water quality standards (WQS) required to sustain these designated uses (EQB, 1990). The SJBE and its tributaries have been classified based on the criteria established by the EQB. (See Table 1.) A waterbody is considered impaired when it is not suitable for its designated uses (Carpenter, *et al.*, 1998).

The EQB is the agency responsible for issuing swimming advisories. A beach closure is implemented by the agency in charge of that particular beach (e.g., DNER, municipality, etc.). However, with the exception of the Condado Lagoon and beaches in the 1970s, no beach closures or swimming advisories have been issued in the SJBE system.

Table 1. Water quality classifications within the SJBE.

Classification	Definition	SJBE Waterbody
SB	Coastal and estuarine waters intended for use in primary and secondary contact recreation and for the propagation and preservation of desirable species.	Condado Lagoon[1], Suárez Canal[2], La Torrecilla Lagoon[2], Piñones Lagoon
SC	Coastal waters intended for uses where the human body may come in indirect contact with the water (such as fishing, boating, etc.) and for use in propagation and preservation of desirable species.	San Juan Bay, San Antonio Channel, Martín Peña Channel[2], San José Lagoon[2]
SD	Surface waters intended for use as a raw source of public water supply, propagation and preservation of desirable species, as well as primary and secondary contact recreation, but precluding primary contact if the waters contain pathogenic organisms at a concentration greater than 2,000 colonies/100 mL of fecal coliforms.	Malaria Canal[2], Puerto Nuevo River, Juan Méndez Creek[2], San Antón Creek, Blasina Creek[2] (including respective tributaries)

[1] From 1973-1979, the EQB posted signs indicating that it was hazardous to swim in the waters of the Condado Lagoon and Beaches. Once WQS were met, the EQB removed the warning signs. In March 2000, the EQB and DNER recommended that the public avoid swimming in the Condado Lagoon due to high fecal coliform levels (no warning signs were posted).

[2] This waterbody is not currently in compliance with its water quality classification.

Point Source Pollution

The promulgation of the WQS in 1974, in addition to other related environmental conservation measures, forced government and private institutions to increase their efforts to protect Puerto Rico's water resources, including those found in the SJBE. These efforts focused primarily on reducing the flow of pollutants by regulating point source discharges. The primary point sources of concern in the SJBE include raw sewage discharges, sewage treatment plant bypasses, combined sewer overflows, and marina or boater sanitary discharges. These sources can contribute nutrients, pathogens, and toxic contaminants to the estuary system.

Sewage Treatment Plants

Until 1957, when the Puerto Nuevo Sewage Treatment Plant was built, San Juan Bay received untreated wastewater from San Juan and other bordering cities. Dissolved oxygen (DO) measurements taken as early as 1947 showed that the bay's waters had DO concentrations less than 4.0 mg/L, a level established in the WQS as the minimum permitted in coastal waters to guarantee water quality (Hydroscience, Inc., 1975). However, even after the construction of the Puerto Nuevo Sewage Treatment Plant, the inner bay continued to be affected by the plant's "poorly treated" discharge (Hydroscience, Inc., 1975). As a primary treatment facility, this plant was designed to remove only the solids from wastewaters, leaving between 50 to 55 percent of the pollutants in the discharge (Water Environment Federation, 1985). Although the Puerto Nuevo Sewage Treatment Plant was upgraded after 1975 to receive 72 million gallons per day (MGD) of sewage, it was the rerouting of its discharge to an ocean outfall in 1985 that helped eliminate this point source and its direct effect on San Juan Bay (Pacheco, 1998). Point sources from other industrial facilities, such as the Cervecería Corona Brewing Company, Caparra Dairy, the Gulf Caribbean Refinery, and Molinos de Puerto Rico, also began to be regulated around this time.

Raw Sewage Discharges

The Vistamar, Villa Carolina, and Round Hills treatment plants have a similar history. These plants discharged into the Blasina Creek, and eventually to La Torrecilla Lagoon, until their effluents were rerouted to the Carolina Regional Sewage Treatment Plant in 1986. This regional facility offers primary treatment and discharges its effluent through an ocean outfall. Until 1986, more than half of the flow in the Blasina Creek corresponded to the discharges of the three treatment plants (Ellis and Gómez-Gómez, 1976). Areas in La Torrecilla Lagoon that were affected by treated and untreated sewage waters, such as at the outlet of Blasina Creek, reported DO levels that ranged between 1.0 and 3.4 mg/L (Candelas, *et al.*, 1967).

Sewage Treatment Collection System Overflows

Overflows from sewage pumping stations are a point source of pollution affecting the SJBE. Several sewage pumping stations have discharged their waters into storm drains or the estuary's tributaries due to mechanical failures associated with over-capacity operations (EQB, 1992). Over the past several years, improvements to the sewage collection system in the SJBE area have reduced the number and frequency of pumping station overflows; however, these overflows do still occur. In 1999, citizens from the Vistamar Marina residential area, adjacent to the La Torrecilla Lagoon, formed a group known as Ciudadanos del Mangle, to seek solutions to the overflows from the Vistamar sewage collection system as well as other environmental problems affecting their community. This group engaged a private laboratory to sample and analyze the quality of the receiving waters affected by the discharges. The analysis revealed fecal coliform concentrations in the Guadalquivir and Managua lakes, two man-made embayments in La Torrecilla Lagoon, as high as 62,500 colonies/100mL and 1,400 colonies/100mL, respectively (High Technology Laboratory, 1999). These values are in violation of the WQS for fecal coliforms applied to La Torrecilla Lagoon (400 colonies/100mL). (See Table 1.) USEPA recently conducted inspections to identify existing problems in the operation of sewage pumping stations in the SJBE (Eng. Pedro Modesto, USEPA, personal communication, 1999). Bypasses from many pumping stations were confirmed. The implementation of a regular maintenance and upgrading program is recommended in this Management Plan to address this problem.

Combined Sewer Overflows

Combined sewer overflows (CSOs) are another point source that contribute nutrients and pathogens to the estuary. Combined sewers are pipes that carry both wastewater and stormwater. During heavy rainfalls, combined wastewater and stormwater flows can exceed the capacity of the sewer pipeline and/or the capacity of the receiving sewage treatment plant. Excess flows are then diverted, discharging untreated sewage and contaminated stormwater directly into receiving waterbodies. These excess flows are called combined sewer overflows. Combined sewers can also overflow during dry weather due to structural problems in the drainage system, physical blockages of the flow regulators, and ground water infiltration into the system (Horsley & Witten, Inc., 1995). Although combined sewers are no longer constructed, they are still in operation in many older urban areas such as the San Juan Islet, Miramar, and Santurce. Eliminating CSOs, through the construction of a sewer system that would independently collect storm waters and sewage for their appropriate disposal, is the most effective alternative for addressing this source of pollution. However, new construction is very expensive and time consuming. As an alternative, a maintenance program to repair collapsed and clogged pipelines could be initiated to stop the discharges that occur during dry weather periods. This solution should also include sanitary sewers, since some of these could be obstructed or collapsed, discharging their contents through manholes and reaching storm sewers that eventually end up in the estuary (EQB, 1996; Junta de Calidad Ambiental, 1994, 1996). This Management Plan recommends the control of CSO sewage discharges reaching storm water collection systems such as the Baldorioty De Castro and Stop 18 storm water pumping stations. In the meantime, opportunities to replace existing combined sewers should be identified when infrastructure improvements are being planned or developed.

Marina Sanitary Discharges

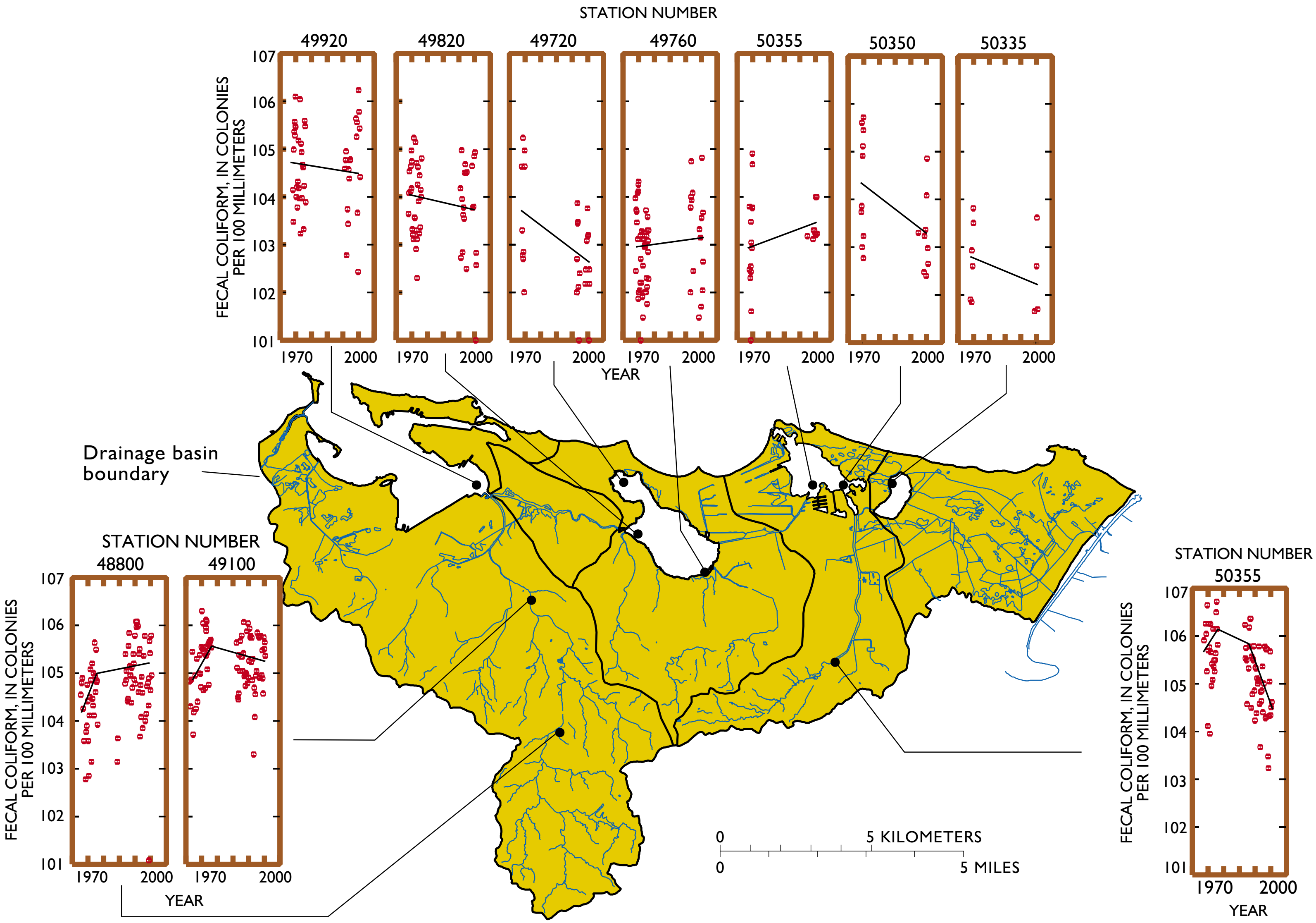
Individual discharges from vessels and marinas are relatively small in scale within the SJBE, but their combined effects can significantly degrade water quality and marine habitats. In addition, the areas where vessel sewage discharges occur are particularly vulnerable (Sealand Technology, Inc., 1994). Typically, marinas are located in embayments that are well protected from waves and wind where there is minimal flushing (USEPA, 1994). The nutrients and pathogens in raw sewage as well as substances commonly used in treating vessel sanitary waste, such as chlorine, quaternary ammonia, and formaldehyde, can pose threats to human health and the marine environment, especially if present in substantial, concentrated amounts (USEPA, 1994). In the SJBE there are four marinas and other docking facilities that do not have appropriate facilities for the disposal of vessel-generated sewage. The installation of fixed or portable pumpout stations to transfer boater wastes into the publicly owned sanitary sewer system is being sponsored in part by the DNER and NOAA's Sea Grant Program. The provision of pumpout facilities is a relatively simple solution for handling sewage discharges from recreational vessels in the estuary.

Marina.

Use Impairments Associated with Contributions of Nutrients and Pathogens

The relocation of sewage treatment plant outfalls to ocean sites outside the estuary was a major step in improving the water quality of the SJBE. Dramatic changes have occurred in areas that once received the direct discharges of sewage treatment plants such as the Blasina Creek and La Torrecilla and Piñones Lagoons (Webb and Gómez-Gómez, 1998). No use impairments due to nutrient loads (nitrogen and phosphorus) have been reported in most of San Juan Bay following the elimination of the Puerto Nuevo Sewage Treatment Plant outfall into this area (Tetra Tech, Inc., 1992). The control of oxygen-consuming substances other than sewage discharges (e.g., industrial discharges), has gradually improved the dissolved oxygen levels in the estuary system. Dissolved oxygen levels in the SJBE lagoons have been stabilizing, decreasing the frequency of highly eutrophic conditions (Webb and Gómez-Gómez, 1998). However, fecal coliform pollution and nutrient enrichment continue to be significant problems. This is evidenced by the fact that, since 1985, in many areas around the estuarine system, there has been a gradual increase in the number of bacteria density samples that exceed water quality standards (Tetra Tech, Inc., 1992). San Juan Bay continues to have concentrations of fecal coliforms well above the WQS. Also, water quality samples obtained at three stream sites and seven estuary sites during the past 20 years indicate that domestic wastewater discharges to streams persist (Webb and Gómez-Gómez, 1998). Fecal coliform counts and trends are shown in Figure 4. High fecal coliform concentrations are mainly responsible for the non-compliance status of some SJBE waterbodies shown in Table 1. The EQB is responsible for informing the public when WQS are exceeded and/or beach closures are warranted.

Figure 4. Fecal coliform counts and trends at selected stations in the SJBE Program area for the period 1970-95. (Source: Webb and Gómez-Gómez, 1998.)



San Juan Bay Estuary Program

Pathogen or disease-bearing contaminated waters have been reported in well-flushed areas such as the outer region of the bay where health-based enterococcus bacteria goal-limits of 35 counts/mL have been exceeded. (While measurements of fecal coliform in ambient waters have been used in Puerto Rico as standards for evaluating pathogen water quality, enterococcus bacteria correlate better with the various viruses and bacteria commonly found in sewage-contaminated tropical coastal waters such as those in the SJBE [Tetra Tech, Inc., 1992]).

It has become clear that the traditional approach of focusing solely on point sources to control specific contaminants does not ensure the protection or improvement of the estuary's water quality. Pollutants from nonpoint sources seem to be the leading cause of the continuing eutrophication and pathogen contamination problems in the estuary (CSA Architects and Engineers/Weston, Inc., 1999[a]).

Nonpoint Source Pollution

Nutrients and fecal contamination from nonpoint sources, such as illegal connections to storm sewers, direct discharges from unsewered areas, and faulty on-site septic systems, continue to occur within the SJBE. These inputs of nutrients from untreated wastewater affect the quality of the estuary's waters and limit the ability for further improvement.

Illegal Sanitary Discharges

Illegal connections of sanitary sewers to storm sewers, as well as direct discharges, have been reported throughout the SJBE and its watershed. However, this condition is most common in the communities closest to the estuary (EQB, 1994; 1996; Junta de Calidad Ambiental, 1989). In a study performed by the EQB from 1986 to 1989, almost 40 percent of the structures surveyed in the communities adjacent to the Martín Peña Channel were found to discharge their raw sewage into storm sewers or directly in the estuary or its tributaries (Junta de Calidad Ambiental, 1989). The illegal sewage discharges draining into several of the storm water pump stations located in the SJBE are so significant that some stations have to operate on a daily basis, even during dry periods, to avoid a backflow of wastewater and overflow through city manholes.

To address these problems, this Management Plan recommends the construction of a sanitary sewer system for those communities bordering the estuary that lack this service, such as those fringing the eastern half of the Martín Peña Channel. These systems would be connected to existing regional treatment plants. The process for identifying illegal connections between sanitary and storm sewers, through methods such as the surveys performed by EQB, should continue in order to eliminate this practice. A similar effort undertaken in the Condado Lagoon during the 1960s and 1970s proved that these two actions are the most effective and efficient way to eliminate direct sewage discharges to the estuary as well as discharges via storm sewer connections (Rivera-Cabrera, 1990).

On-Site Septic Systems

An on-site septic system is comprised of a septic tank and a leaching facility. The septic tank provides for the separation of solids and liquids and some treatment. The leaching facility serves to dispose of the liquid wastes. If a septic tank is not properly maintained, solids may pass to the

Illegal sanitary discharges.

leaching facility, causing plugging, backups into the dwelling, or discharge of effluent up to the surface. Even if functioning properly, the cumulative effects of numerous small septic systems may result in excessive nutrient concentrations in ground water and down gradient surface waters. These impacts are dependent upon the location of septic systems relative to water resources and the overall septic system density (Horsley & Witten, Inc., 1995). Many communities located in the rural areas of the upper SJBE watershed, such as Caimito and Cupey, dispose of their sanitary wastes in on-site septic systems. At the present time, there is no information about the number of septic systems working properly or inefficiently and the frequency of maintenance on these systems. The on-site septic systems found in these and other regions of the estuary have the potential to be significant sources of nutrients and pathogens. Monitoring programs and inspections should be initiated to help assess the potential impacts of these systems on the SJBE. The Municipality of Carolina is in the planning stages of such a monitoring program.

Public Health Concerns Associated with Untreated Sewage Discharges

In general, the eutrophication of surface waters can trigger an increase in the population of many organisms, that, when present in high numbers, are responsible for a variety of human ailments. Elevated populations of naturally occurring algae such as Cyanobacteria, or blue-green algae, can cause health problems ranging from skin irritation from direct contact to stomach problems from ingestion (Horsley & Witten, Inc., 1995). Although untreated sewage discharges are considerable throughout the SJBE, there are no reports of people suffering from these ailments due to contact with estuary waters or consumption of estuary products. It is the introduction of microbial pathogens or infectious diseases that poses the greatest public health threat associated with the discharge of raw or partially treated sewage into surface waters. Human infectious diseases associated with swimming in sewage-polluted waters and consumption of contaminated shellfish include hepatitis, typhoid, cholera, skin diseases, acute gastroenteritis (AGI), and a rare but fatal disease known as septicemia (blood poisoning). (Appendix F describes some of the diseases that are often associated with untreated sewage discharges to surface waters.)

In the SJBE, high levels of fecal coliforms are indicative of pathogen contamination. However, at the present time, there is not enough information available specific to the SJBE to definitively relate the occurrence of pathogens with raw sewage discharges or to relate the occurrence of diseases, such as those mentioned above and elsewhere in this section, with contaminated waters. Information that could clarify possible health risks due to direct or indirect contact with SJBE waters is extremely limited. Nevertheless, studies from the SJBE and other estuarine systems clearly indicate that the potential for such diseases is a concern, based on the data on pathogen contamination in SJBE waters that is available.

The most common form of disease in humans that is associated with exposure to biological pathogens in the marine environment is AGI, which is caused by Norwalk viruses, other viruses, and various species of bacteria (Tetra Tech, Inc., 1992). The incidence of AGI has been correlated with increases in nutrient loading, particularly from agricultural runoff, urban runoff, and sewage discharges. The potential for exposure to this and other diseases by direct or indirect contact with contaminated waters exists at selected sites of the estuary such as La Torrecilla, San José, and Los Corozos Lagoons, where fecal coliform standards have been exceeded after rain events (Webb and Gómez-Gómez, 1998). A significant risk exists in some areas of the SJBE such as the Martín Peña Channel, where fecal coliform concentrations ranging from 270,000 to 2,000,000 col/100 mL have been reported (Webb and Gómez-Gómez, 1998). These concentrations exceed by at least 60 times the WQS established for SC waters.

Children fishing blue crabs at San José Lagoon.

The SJBE Program sponsored a study to determine the public health risks from direct and indirect contact activities such as bathing and fishing at 16 sites in the SJBE (Seguinot-Barbosa, 1999). The sites sampled for fecal coliform concentrations are traditionally used for activities such as bathing, swimming, and water sports. The study also utilized a public poll to try and determine possible links between illnesses experienced by citizens and the consumption of fish and other products from the estuary. Single samples taken from each of the surveyed sites led to the conclusion that risk levels associated with water contact activities were within acceptable levels, although six of the sites exceeded WQS for fecal coliform concentrations. More than 40 percent of those interviewed consume food from estuary waters, but none reported any illness as a result. However, pathogens and pathogen indicators, other than coliforms, are not routinely monitored in Puerto Rico's estuarine waters and detailed studies are not conducted to relate diseases to the ingestion of fish and shellfish from these waters (Tetra Tech, Inc., 1992). Although diseases could occur, these are not necessarily linked to pathogenic seafood or direct contact with contaminated waters. Since fecal coliform standards have exceeded acceptable limits for shellfish ingestion in the San Juan area, there is a need for an epidemiological approach to evaluate the extent of this impairment (Tetra Tech, Inc., 1992).

Stormwater Runoff

The SJBE is also affected by other types of pollutants that reach the estuary through storm sewers or runoff. Rainfall can wash nutrients, metals, oils, and other substances from urban impervious surfaces such as roads, sidewalks, and parking lots into surface waters. The concentration of contaminants in this runoff depends on the extent of the source, the type of contaminant, the intensity and duration of the storm, and the timing between storms. Highest contaminant concentrations are generally found in the first flush of runoff that is generated at the beginning of a storm. "Runoff from paved areas has a lower concentration of dissolved nutrients than septic systems or lawn fertilizer sources. However, the total volume of runoff can be much greater than the volume from other sources, making the contribution significant" (Horsley & Witten, Inc., 1995).

Coastal waters normally receive substantial amounts of pollutants that are transported by runoff. Tanker accidents, involving ships, barges, or towed vehicles account for only 5% to 10% of all oil discharged in the ocean, while the remaining 90% to 95% comes from land-based sources, such as improperly disposed dirty oil from automobile engines (Ornitz, 1996).

In addition to sewage discharges, typical pollutants released to surface waters from stormwater runoff include petroleum hydrocarbons (e.g., oil, gasoline, and greases) from vehicles, marinas, or port facilities, and pesticides, fertilizers, metals, sediments, and pollutants related to certain industrial processes and practices. Metals (copper, cadmium, zinc, lead, and nickel) are also significant pollutants normally washed from paved surfaces (Horsley & Witten, Inc., 1995).

Pollutants from nonpoint sources present in the SJBE watershed, and especially those carried by runoff, account for many of the nutrients and other loadings to the estuary when compared to those contaminant contributions discharged during dry periods or low flow events (Gómez-Gómez, *et al.*, 1983). Pollutant discharges related to fecal coliform loadings occurring during dry periods and low flow events are nevertheless considerable, since these have been found to exceed by more than four times the WQS in tributaries such as the Buena Vista, Juan Méndez, and San Antón Creeks (CSA Architects and Engineers/Weston, Inc., 1998). Activities that degrade SJBE tributaries impact the physical, chemical, and biological processes of the estuary and therefore play a major role in defining the quality and many of the characteristics of the estuary. The SJBE Program believes nonpoint sources of pollution represent a substantial threat to SJBE water quality.

Sanitary landfills generally represent a significant source of metals, nutrients, pesticides, pathogens, and synthetic organic compounds. Many household hazardous wastes, such as paints and cleaning products, are disposed in landfills. Since landfill surfaces are typically devoid of vegetation, rainwater percolates or filters down through them, leaching contaminants from refuse into the underlying ground water or into nearby surface waters (Horsley & Witten, Inc., 1995). The SJBE watershed contains regional landfills for the San Juan and Carolina municipalities. These were established by the mid-20th century when proper management measures, such as separating the collected materials (including hazardous wastes) and placing liners beneath landfills, were not required or available (Municipio de San Juan, 1998). In addition, the location of the Carolina and San Juan landfills and their proximity to the SJBE make them a highly probable and significant source of pollutants to the estuary. There are no data on the types and volume of potential pollutants from sanitary landfills, information that would be essential for any control measures. Although federal and local statutes regulate large-scale hazardous materials use, household use of small amounts of hazardous materials is not adequately managed. The general public should have easily accessible options for the proper disposal of household hazardous wastes.

False mussel (Mytilopsis dominguensis). *Courtesy of Luz María Yoshiura.*

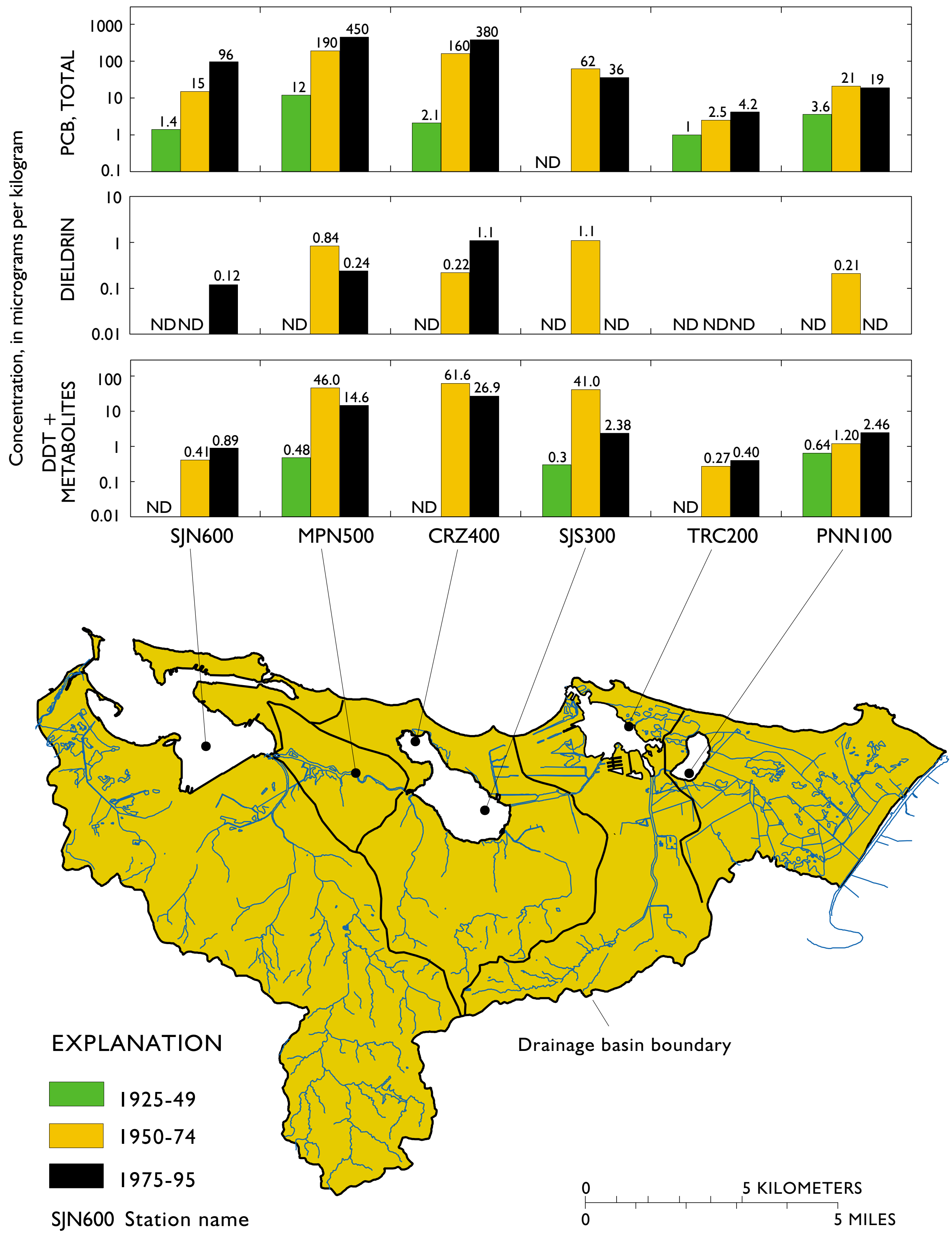
Toxic Contaminants

Most of the pollutants carried by stormwater runoff, especially metals, settle and accumulate in silts and muds, called sediments, on the bottoms of waterbodies such as rivers and estuaries (Horsley & Witten, Inc., 1995; USEPA, 1997[a]). Sediments are derived from land-based and organic materials that have been weathered and transported by water flow to waterbodies, gradually accumulating on the bottom, as well as from particles produced and transported by the sea. Sediments have been described as the ultimate sink or storage place for toxic chemical pollutants. When undisturbed and confined by sediments, contaminants are largely prevented from becoming suspended in the water column (Horsley & Witten, Inc., 1995; Webb and Gómez-Gómez, 1998). However, sediments can still function as a source of contaminants in the aquatic environment (Horsley & Witten, Inc., 1995). "Adverse effects on organisms in or near sediments can occur even when contaminant levels in the overlying water are low. Benthic or bottom dwelling organisms can be exposed to pollutants in sediments through direct contact, ingestion of sediment particles," or uptake of dissolved contaminants present in the water saturated sediments (USEPA, 1997[a]). Natural and human disturbances, such as dredging and the resuspension of sediments from vessel traffic, can release contaminants to the overlying water column, exposing many organisms to the contaminants (Horsley & Witten, Inc., 1995; USEPA, 1997[a]).

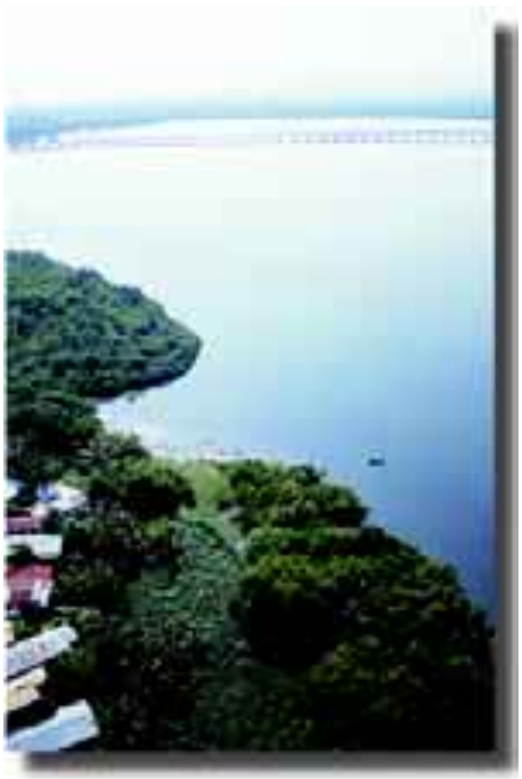
Toxic substances, toxics, or toxicants are defined as elements, substances, or combinations thereof, including disease-causing agents, which after being discharged and after their exposure, ingestion, inhalation, or assimilation in certain concentrations directly from the environment or indirectly by means of ingestion through the food chain, are capable of producing an adverse response such as death, illness, abnormal behavior, cancer, genetic mutation, physiologic malfunctioning (including reproductive malfunction), or physical deformations in an organism, its descendants, or in a biological system (Tetra Tech, Inc., 1992; EQB, 1990).

PCBs, the pesticide DDT (and metabolites DDD and DDE), the common plasticizing agent bis (2-ethylhexl) phthalate (B2EHP), lead, and mercury are the most abundant contaminants found in the sediments of the SJBE system (Webb and Gómez-Gómez, 1998). (See Figure 5.) The effect of these contaminants could range from immediate death (acute toxicity) to long-term illness (chronic toxicity) of organisms, depending on the type and the concentration of the pollutants and the degree of exposure. (Appendix G describes the sources and potential human and environmental health effects of the most abundant toxics found in SJBE sediments.) The control or elimination of historic sources of

Figure 5. PCBs, Dieldrin, and DDT plus metabolites concentrations in bottom sediments for selected stations within the SJBE Program area for the periods 1925-49, 1950-74, and 1975-95. (Source: Webb and Gómez-Gómez, 1998.)



pollutants responsible for sediment contamination has reduced loadings to the estuary system. PCBs, dieldrin, and DDT and its metabolites entered the commercial market during the 1940s. However, because of health and environmental hazards associated with their use, the manufacture of these organochlorinated compounds was banned in 1977, 1974, and 1972, respectively (U.S. Agency for Toxic Substances and Disease Registry, 1997, 1993, 1989). These contaminants are now less frequently found in surface waters than in the past. Their occurrence in SJBE sediments is also expected to decrease with time, except for PCBs which are found in sealed transformers that are still in service. The discontinued use of leaded gasoline in 1985 probably resulted in a decline in the concentrations of lead measured in water samples from the Río Piedras River and Blasina Creek from generally more than 10 mg/L before 1985, to less than 5 mg/L in recent samples (Webb and Gómez-Gómez, 1998).



San José Lagoon junction with the Martín Peña Channel.

Although the trend of toxic loadings seems to be decreasing, recent data obtained in the SJBE indicate that toxic pollutants in bottom sediments in areas such as San Juan Bay and Los Corozos Lagoon may persist at relatively high concentrations in the top layer for some time (Webb and Gómez-Gómez, 1998). It takes a long time for these contaminated sediments to be buried by incoming sediments, since there is an average sediment depositional rate of about 5 cm per decade (Webb and Gómez-Gómez, 1998). Also, the slow break down rate of these pollutants significantly increases the years of potential exposure to aquatic organisms (U.S. Agency for Toxic Substances and Disease Registry, 1997, 1993, 1989; USEPA, 1997[a]). For these reasons, Webb and Gómez-Gómez (1998) concluded that contaminated sediments in areas of the estuary such as the Martín Peña Channel and the San José and Los Corozos lagoons "present a potential threat to human health". However, USEPA reviewed their report and concluded that, based on the confined nature of the contaminated sediments, there was no threat to human health by direct contact. This determination certified that a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) removal action, to identify and clean a hazardous waste site, was not warranted (USEPA, 1996).

Public Health Concerns Associated with Toxic Contaminants

Benthic organisms can accumulate pollutants in their tissues, a process known as bioaccumulation. Since these organisms are a food source, the accumulation of organic compounds and metals in their tissues may represent a major link in the transport of such toxics to fish and subsequently to humans. "In fact, the consumption of fish represents the most significant route of aquatic exposure of humans to many metals and organic compounds (USEPA, 1992[a]). Most sediment-related human exposure to contaminants is through indirect routes that involve the transfer of pollutants out of the sediments and into the water column or aquatic organisms." (USEPA, 1997[a]). The primary exposure route to PCBs, DDT (and metabolites DDD and DDE), and B2EHP in the SJBE sediments through direct contact activities such as swimming is dermal absorption. This exposure route does not appear to be significant for heavy metals, such as mercury and lead, because these cannot penetrate the skin (Tetra Tech, Inc., 1992).

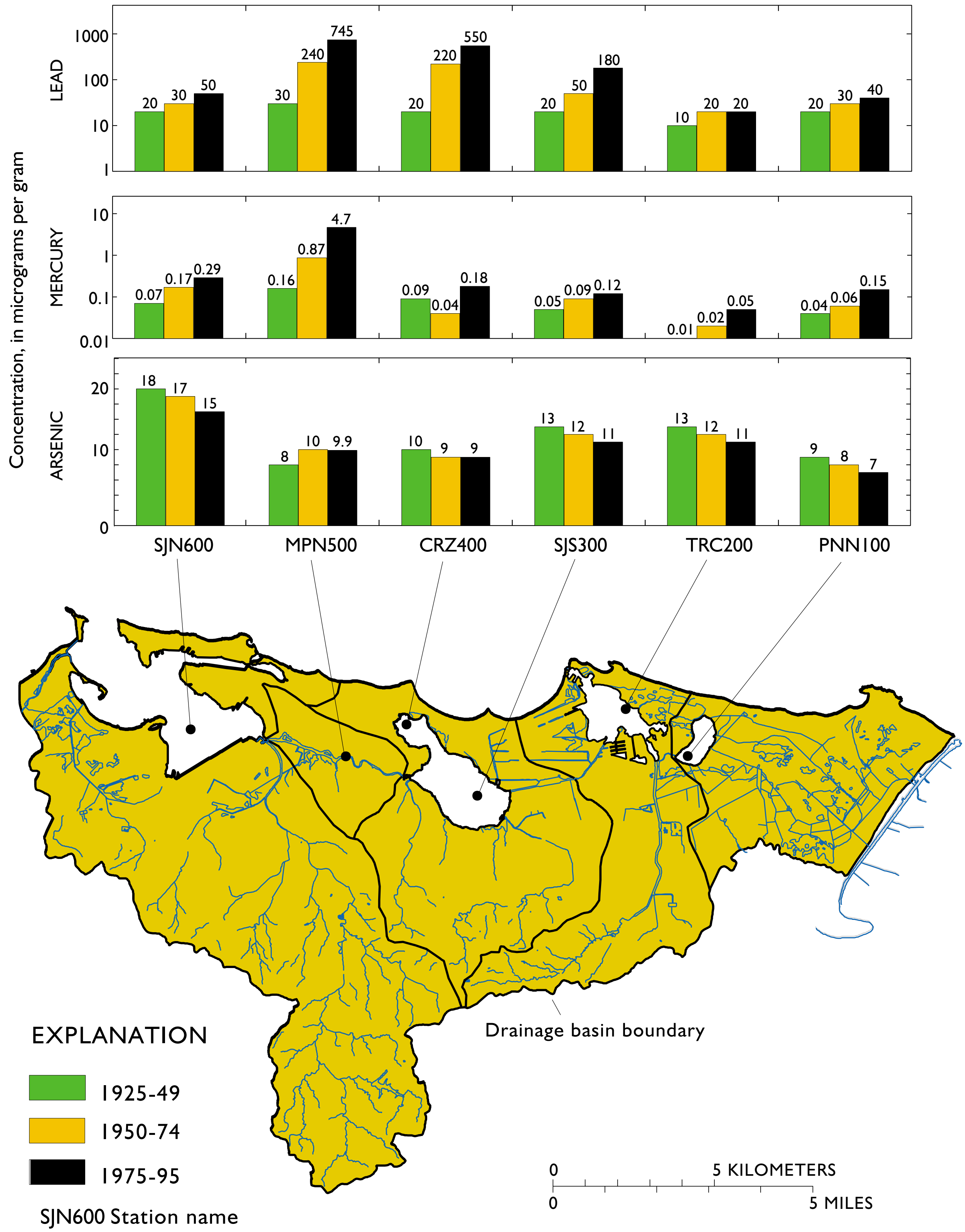
Local fisherman showing a particularly big blue crab (Callinectes sp.).

A study sponsored by the SJBE Program to investigate the levels of seven heavy metals in tissues of the striped mojarra (*Diapterus plumieri*), the blue crab (identified as *Callinectes sp.* in this study, although *Portunus sp.* also may be included), and the false mussel (*Mytilopsis domingensis*) taken from the San José and Los Corozos lagoons was performed in 1998 (Delgado-Morales, *et al.*, 1999). The study found some values of mercury and lead concentrations above US Food and Drug Administration (USFDA) recommended standard values (Delgado-Morales, *et al.*, 1999). (Lead, mercury, and arsenic concentrations in bottom sediments are shown in Figure 6.) Although in the striped mojarra the average concentration of mercury did not exceed the USFDA standard, two individuals were found to have levels above the standard. The average lead concentration in striped mojarra was above USFDA standard values. Some samples of the false mussel exceeded the USFDA's action level standard for lead, but did not exceed levels for mercury. In the blue crab, neither mercury nor lead exceeded the USFDA standard values. Nevertheless, the consumption of blue crabs could still represent a health problem for those individuals who consume blue crabs on a regular basis. This is not the case for the false mussel, since it is not eaten by humans.

Concerns about the potential health hazards associated with the ingestion of contaminated fish tissue are supported by a 1992 USEPA-sponsored study to characterize use impairments in the waters of the U.S. Virgin Islands and Puerto Rico (Tetra Tech, Inc., 1992). Ambient Water Quality Criteria (AWQC) for the organics and metals were based on the protection of aquatic organisms and their use. (See text box.) The study revealed that for samples taken in the San Juan area (San Juan Bay, Martín Peña Channel, and San José and Los Corozos Lagoons), chronic AWQCs for mercury and acute AWQCs for copper were exceeded by a factor of 10. Zinc and silver levels exceeded the acute AWQCs. Exceedances of chronic AWQCs for B2EHP, lead, and nickel were also reported. Levels of thallium slightly exceeded the AWQC in the San Juan Harbor area (Tetra Tech, Inc., 1992). For human fish consumption, mercury levels far exceeding the AWQC of 0.15 mg/L were calculated for the San Juan area. There is a potential risk to subsistence and recreational fishermen due to the exposure to mercury in fish tissue. In

Key toxics of concern for surface waters, some of which have been found recently in SJBE sediments, were identified by performing a screening analysis that compared statistical summary data stored in USEPA's STORET water quality and biological monitoring data repository with Ambient Water Quality Criteria (AWQC). A compound of concern was selected as a chemical of concern if the maximum concentration detected at any station location within the coastal region exceeded chronic (long-term illness) and/or acute (immediate death) AWQC for the protection of marine life and/or the AWQCs derived for ingestion of fish tissue.

Figure 6. Lead, mercury, and arsenic concentrations in bottom sediments at selected sites within the SJBE area, for the time periods, 1925-49, 1950-74, and 1975-95. (Source: Webb and Gómez-Gómez, 1998.)



summary, this study concluded that the San Juan Harbor area "experienced excessive degradation of the ecosystems and exceedances of 100 times acute AWQCs established for the protection of marine organisms, 100 times human health AWQCs for ingestion of fish, and/or 1,000 times the fecal coliform standards" (Tetra Tech, Inc., 1992). These exceedances were estimated for water quality samples. Due to the nature of these contaminants, an increase in potential health hazards could be expected as a result of gradual precipitation and accumulation in sediments. In areas such as the San José Lagoon, contaminated sediments are spread out as a thin layer less than 8 inches (20 cm) deep, making their handling extremely difficult (Webb and Gómez-Gómez, 1998). At this time, a practical way to diminish direct and indirect exposure may be to avoid significant disturbance of bottom sediments and to cap or confine those sediments with the highest concentration of pollutants.

Local fishermen, Suárez Canal.

In July 1999, the SJBE Policy Committee issued a resolution recommending that fish from the San José Lagoon not be consumed. In that same month, the DNER and the EQB issued a public advisory about the potential risks associated with fishing, extending the Policy Committee recommendation to Los Corozos and La Torrecilla Lagoons, the Martín Peña Channel, and the Suárez Canal, that no products be consumed or ingested from these waterbodies. USEPA guidelines for assessing chemical contaminants data for use in fish advisories suggest intensive follow-up sampling to determine the magnitude of the contamination in edible portions of the species in question and the geographic extent of contamination among various size classes (USEPA, 1995). A follow-up study was initiated in April 2000 by USEPA to assess risks to human health from the consumption of fish and blue crabs. Data obtained will be validated based on the nature and extent of chemical contaminants in representative edible tissues from fish and blue crabs in the San José and Los Corozos Lagoons, and a quantitative risk assessment for the consumption of these organisms by children, pregnant women, and adults will be completed. USEPA will also provide assistance for the issuance of risk-based health advisories based on the study results.

Spills

Ninety to ninety-five percent of all oil discharged in the ocean comes from land-based sources. The remaining 5 to 10 percent corresponds to vessel-related oil spills. Such spills normally have a long lasting effect in coastal areas such as estuaries (Ornitz, 1996). This effect is not only due to the large quantities often involved but also due to the low energy (sheltered) characteristics that make these systems very vulnerable. Flushing or scouring by waves and currents in estuaries is poor and the residence time of pollutants is long, allowing chronic effects on sensitive organisms from pollutants such as oil (Cintrón, *et al.*, 1985). Puerto Rico relies heavily on maritime shipping for products and supplies, such as fuel oil for its energy needs. The San Juan Bay port area handles 80 percent of all cargo entering and leaving the Island, and this increases the likelihood of collisions or groundings and the potential discharge of hazardous materials in this area due to intense shipping traffic. Several major oil spills have occurred in the Bay area in the past. Some of these include:

- *Ocean Eagle* (March 1968): Approximately 83,400 barrels (3,502,800 gallons) of light Venezuelan crude spilled into San Juan Harbor when the ship broke in two; 16 miles (26 km) of the shoreline were oiled.

- *Z-102* (December 1975): Approximately 7,679 barrels (322,518 gallons) of Bunker C fuel oil spilled when the barge grounded on a reef at the northwest entrance to San Juan Harbor; this accident caused slicks from Isla Verde to Dorado Beach on the north coast of Puerto Rico.

- *Morris J. Bergman* (January 1994): Approximately 19,000 barrels (798,000 gallons) of No. 6 fuel oil spilled into the sea at Punta Escambrón, affecting the Condado Lagoon, when a tugboat lost its tank barge that ran onto a reef (Ornitz, 1996).

The best way to avoid shipping accidents and resulting oil spills is through prevention (Ornitz, 1996). This Management Plan recommends the creation of a board of pilot commissioners that will help in the development of piloting and harbor safety measures to reduce the possibility of oil spills from shipping accidents in areas within and around the SJBE.

Thermal Pollution

Solid and liquid wastes are not the only agents responsible for the degradation of the SJBE's waters and sediments. The Puerto Nuevo Power Plant and the Palo Seco Power Plant, located in the southwest corner of San Juan Bay and on the Palo Seco Peninsula, respectively, discharge millions of gallons of hot cooling waters into the bay as part of their electric generating process. This type of contamination, known as thermal pollution, substantially increases the temperature of the bay's waters, reducing their capacity to retain oxygen and thus their potential for sustaining fisheries and other aquatic resources. Studies have been conducted as part of the permit requirements for power plant operation, but the impact of these facilities on the overall health of the aquatic environment is not well understood. A comprehensive effort is suggested as part of this Management Plan to gain a better understanding of this problem in order to take the necessary steps to reduce potentially harmful effects.

Docks, other Watercraft Infrastructure, and Boat Operations

The high density of people living within the SJBE has contributed to an increase in the number of docks, boating activities, and related infrastructure (marinas, fishing associations) located within the estuary. While boating infrastructure is needed to provide access to the waters of the SJBE, and boating activities represent a popular way to enjoy the waters and resources of the SJBE system, care must be taken to minimize the potential adverse impacts on the estuary system associated with these facilities and uses.

Impacts associated with docks and related boating infrastructure will vary depending on the type and complexity of the structure in question. Impacts include the effect of shadowing, the replacement and alteration of natural coastlines with man-made structures, and pollution generated by fueling, motorboat repair, and boat cleaning detergents. The wood used in the construction of docks and related structures is another source of water pollution. Wood used in the construction of docks is typically protected with chemical treatments to prevent damage by fungus and borers and to increase its longevity. Preliminary studies have indicated that leaching from these chemicals and paints can affect the water quality and marine fauna and flora of a particular area (WHOI, 1998).

Northern La Torrecilla Lagoon.

The impact of docks and related structures on a particular area will be proportional to the quantity, type, and size of the structures. Cumulative impacts to an area should be considered since a significant number of small docks could have an effect similar to an entire marina. Several illegal docks and other similar structures have been identified within the SJBE system, most notably in La Torrecilla, San José, and Los Corozos Lagoons, the Suárez Canal, and Blasina Creek. The SJBE Program understands the necessity for docks, ramps, and other related infrastructure to guarantee public access to the water; however, the construction of recreational infrastructure for public use should be located in areas to minimize ecological damage.

One of the main impacts of docks and related structures on a particular area is the quantity of watercraft that they attract. Boating activity can result in sediment and contaminant resuspension and resultant turbidity, increased turbulence, laceration and scarring of aquatic vegetation (resulting in loss of faunal habitat and substrate stability), toxic chemical emissions from boat engines, and physical and physiological damage to aquatic organisms.

Laceration of aquatic vegetation such as scarring by boat propellers is one of the main impacts adversely affecting SAV beds in estuaries and other coastal areas. A study being conducted within the SJBE system by NMFS using Side Scan Sonar has indicated the presence of propeller scars in the bottom of La Torrecilla Lagoon. Available data indicate that propeller scarring can last for many years. Boat anchors can also adversely affect SAV, coral communities, and other benthic communities by direct physical impact. Consequently, there is a direct adverse effect on all organisms (fish, invertebrates, and algae) associated with these habitats.

Impacts will vary depending on the type of watercraft and the activity in question. For example, motorized personal watercraft (MPWC), commonly known as jet skis, are a unique and relatively new type of recreational vehicle. MPWC are designed to be operated at high speeds, and their small size and shallow draft make them more maneuverable and allow operation close to shore in shallower water than other motorized watercraft. These characteristics increase the potential for damage to nearshore habitats and associated organisms. Anecdotal information indicates the presence of a significant number of MPWC on a frequent basis within the SJBE system, particularly in La Torrecillas, San José, and Los Corozos Lagoons, the Suárez Canal, and Blasina Creek. Due to the impact of MPWC on shallow environments and to other users, regulations restricting and banning this type of watercraft have been established in many states, including New Hampshire, Washington, Florida, and the City of San Francisco (Audubon Society, 1998). In 1998, the Bluewater Network Association indicated that 48 states have restricted the use of MPWC in certain areas under their jurisdictions.

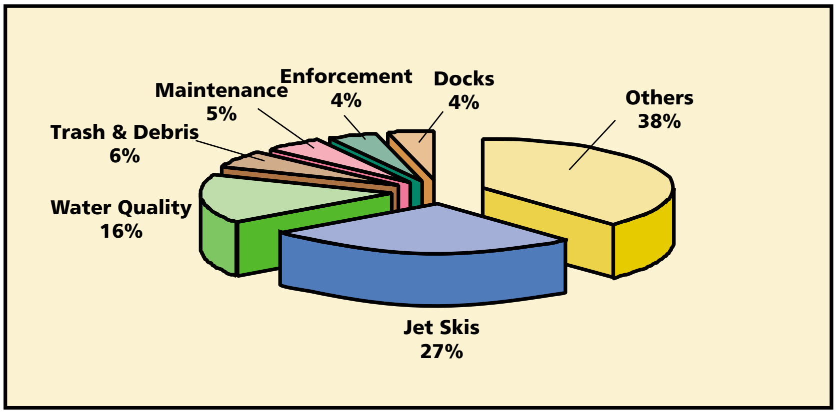
MPWC usually have a two-stroke engine that discharges more fuel than the four-stroke engines found on conventional recreational boats. According to the Bluewater Network Organization, USEPA found that MPWC emit up to 30 percent of their raw fuel directly into the water. Also, it is indicated that, based on fuel consumption, MPWC dump 1.5 to 4.2 gallons of fuel directly into the environment during every hour of use, producing significantly higher emissions than conventional motorboats.

Boat emissions have been documented to have detrimental effects on living resources. Substances of concern from outboard motors include fuel, oil, and pyrogenic PAHs. Data indicate that Naphtalene and other two-and three-ring compounds found in fuel/oil mixtures can be acutely toxic at 0.3 to 4 parts per million (WHOI, 1998). Carbon fixation has been shown to decrease by 50 percent in plants when exposed to 0.2 to 10 parts per million levels. Emissions produced by engines contain substances that have a negative impact on fish, including fish in early life stages. Disruption of normal biological functions has been observed at different levels of biological organization including sub-cellular, cellular, physiological functions, and histopathology (see references in WHOI, 1998). Moreover, levels of PAHs can accumulate over time in soft bottom sediments and when disturbed can become available to benthic organisms. This can lead to bioaccumulation throughout the food chain into the flesh of animals and plants that in some cases are incapable of metabolizing this type of compound (WHOI, 1998).

The feeding and reproductive behavior of marine mammals, such as the West Indian Manatee and sea turtles, are adversely affected by boating activities. In addition, these animals are affected by direct physical damage from vessel impacts. Available data for Puerto Rico indicate that capture by humans and collision with watercraft account for over 48 percent of all manatee deaths (Mignucci-Giannoni, *et al.*, 2000). Researchers note that MPWC disturb more marine mammals than other watercraft due to the facts that MPWC run faster, on varying courses, and frequently change direction and speed, whereas other types of watercraft move in a more linear course without major changes in speed. In addition, because MPWC do not emit low-frequency, long distance underwater sounds, surfacing mammals or birds are not warned of approaching danger until they are in close proximity.

Research performed in the Everglades indicated that fishing success dropped to zero when MPWC were present in the area (WHOI, 1998). Although studies quantifying the fishing success in the SJBE system are lacking, a creel survey performed within our system indicated that MPWC are the second most important factor affecting fishing activities (Yoshiura and Lilyestrom, 1999). (See Figure 7.) Research in Florida indicates that MPWC cause wildlife to flush at a greater distance, with more complex behavioral responses than to other types of motorized vessels. Declines in the nesting success of certain bird species, such as grebes, coots, moorhens, and osprey, have also been noted (WHOI, 1998). While no specific study measuring the effect of watercraft on bird behavior has been performed in the SJBE system, similar effects could be expected (Rivera-Herrera, 1996).

Figure 7. Topics of concern cited by anglers related to fishing conditions in the San José and La Torrecilla Lagoons. (Source: Yoshiura and Lilyestrom, 1999.)



The SJBE system encourages multiple human uses of its waters that are compatible with natural resource protection. The unregulated use of watercraft has a significant potential to interfere with a large number of current and potential passive users. Therefore, actions addressing the regulation of watercraft and the number of docks and related structures within the SJBE system are included within this Management Plan.

Erosion and Sedimentation

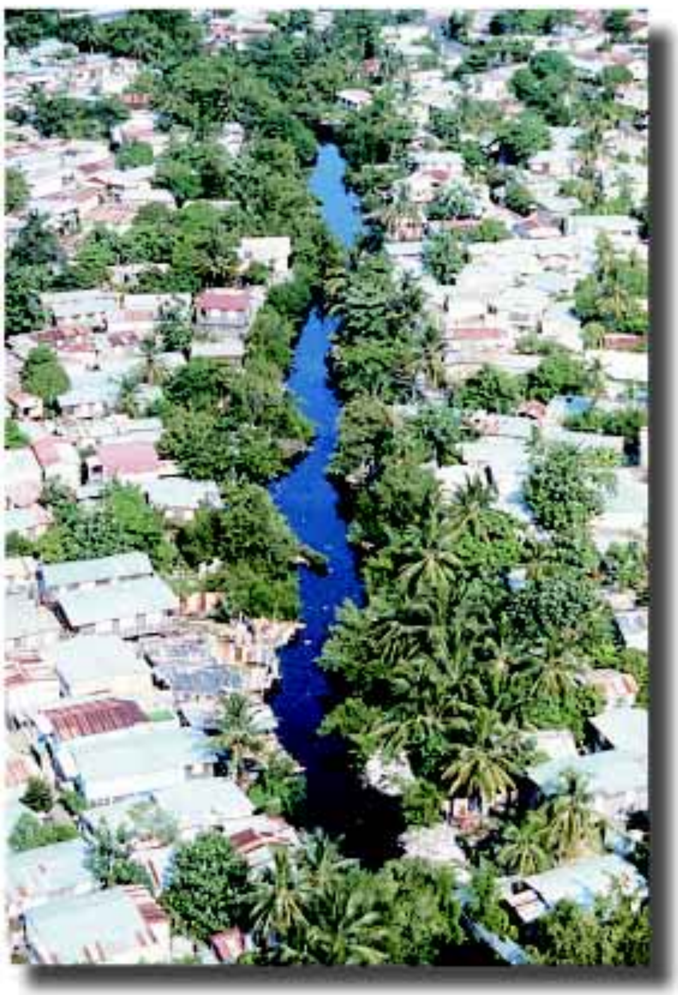
The urbanization of drainage basins, the removal of instream vegetation, and the alteration and removal of vegetation from the banks of streams and rivers all contribute to erosion and sedimentation and the degradation of water quality in SJBE tributaries. Vegetation within the drainage basin and along tributaries retains sediments and other pollutants that would otherwise flow to the estuary system. In the upper part of the watershed, erosion accounts for an average loss of 10 cm of soil per year, much of which enters the Río Piedras River (Webb and Gómez-Gómez, 1998). Large quantities of sediments reaching the estuary increase concentrations of suspended solids, and thus water turbidity, hampering the development of light-dependent benthic communities and degrading aesthetics and the suitability of the water for recreation. Silt also carries nutrients to receiving waterbodies, contributing to eutrophic conditions. These high erosion

SJBE's watershed deforestation.

rates could have a significant effect on the Port's vessel handling capacity, since sediments are gradually filling its navigational channels. Efforts to utilize, enhance, and protect natural elements, such as vegetated areas to filter contaminants, are recommended in this Management Plan through the creation of riparian buffers or corridors, besides those measures already identified to reduce pollutant loadings at the source.

Flow Modifications

The estuary has been significantly modified by dredging, channelization, the mining of fill material, the placement of fill material, and sedimentation. These processes affect the lagoons, the bay, channels, and man-made canals by altering the inflow of freshwater and stormwater runoff, changing circulation patterns, and reducing the flushing capacity of waterbodies. The problems associated with pollution in the SJBE are compounded by the limited natural flushing of the system. In Puerto Rico, the tidal ranges are small and the water currents are relatively minimal; the latter is especially significant for the SJBE. As a result, estuarine water flows are small, resulting in an increase in the retention time of the pollutants discharged into the system.



Eastern Martín Peña Channel.

The SJBE was originally separated from La Torrecilla Lagoon and the Piñones Lagoon by an extensive swamp that might have provided a continuous flow of water only during extreme flood events (Sepúlveda-Rivera, 1989). The waterbodies that comprised these "two" separate estuaries were relatively shallow. The Torrecilla-Piñones Lagoon complex averaged 3 feet (approximately 1 m) in depth, while the San José Lagoon, the Martín Peña Channel, the San Juan Bay, and the Condado Lagoon averaged 8 feet (2.5 m) and probably could not have exceeded 22 feet (6.7 m) in depth (Seguinot-Barbosa, 1983; Warren-Evermann, 1900; U.S. Department of Commerce, 1976; Ellis, 1976).

Human impacts to the estuary's hydrology began in the Condado Lagoon during the 18th century with the construction of a bridge and the San Gerónimo and San Antonio forts, and the placement of rocks to block the passage for large boats from the ocean to the lagoon (Sepúlveda-Rivera and Carbonell, 1988; Ellis, 1976). However, the first significant change in the hydrology of the estuarine system occurred in the 19th century. In the 1820s to 1830s, the Suárez Canal (previously known as Canal de la Pasa) was dug between the San José Lagoon and La Torrecilla Lagoon (Giusti-

Cordero, 1994). This canal allowed a direct and possibly continuous flow between these two lagoons, extending the SJBE to its current limits.

Until the mid-19th century, further dredging and filling activities were restricted mostly to the Condado Lagoon and San Juan Bay. Dredging activities in San Juan Bay began around 1858 (Seguinot-Barbosa, 1983). By 1884, the first dredging involving the entire Bay was commenced (Seguinot-Barbosa, 1983). Filling activities related to port facilities had been taking place for several years on the south side of the San Juan Islet, on the eastern side of La Puntilla and nearby shores (Sepúlveda and Rivera, 1989).

Increased dredging and filling activities during the beginning of the 20th century took place at the bay's entrance channel, the south area of Isla Grande, the San Antonio Channel, and the Condado Lagoon (USACE, 1994[a]; U.S. Department of Commerce, 1976). These activities reduced the circulation in the lagoon and significantly restricted its connection with the inner part of the bay through the San Antonio Channel. During the 1940s, Isla de Cabras was connected to the mainland by the placement of fill material and rubble, reducing considerably the width of San Juan Bay's outlet and, therefore, the exchange with ocean waters (Seguinot-Barbosa, 1983).

The late 1950s marked the beginning of the most intensive period of dredging and filling activity in the history of the SJBE. With the exception of the Piñones Lagoon, which has suffered almost no human alteration to its shape or depth, all of the waterbodies associated with the estuary were greatly altered during this period. These changes affected not only the lagoons and canals individually, but the entire estuary system.

Urban encroachment in the estuary's drainage basin during the last 40 years has led to considerable changes in fresh water inflows. Increases in impermeable surfaces throughout the watershed have reduced the lag time between rainfall and runoff. Consequently, a larger volume of water reaches streams in a shorter period of time. This, in turn, increases the extent and frequency of floods due to the inability of streams to handle larger volumes.

In the past, San Juan Bay received fresh water inputs from the Río Piedras River, San Fernando Channel, and the Bayamón River. The San José Lagoon was connected directly to the ocean by way of San Juan Bay through the Martín Peña Channel. The San José Lagoon received discharges from the Juan Méndez and San Antón creeks. The Condado Lagoon, although united to the bay by the San Antonio Channel, was influenced almost completely by the ocean through its northern outlet located near the area known as El Boquerón. The Piñones and La Torrecilla Lagoons, connected by the Piñones Canal, exchanged water directly with the Atlantic Ocean through the Boca de Cangrejos outlet. They both normally received fresh water from the Blasina Creek, but during extreme flood events they also received flow from the Río Grande de Loíza. The only waterbodies known to have received ground water were the San Juan Bay, the Martín Peña Channel, and the San José Lagoon. However, the water discharged from the aquifer was and still is relatively insignificant, discharging mainly to streams within the lower parts of the basin, when compared to surface waters (Gómez-Gómez, 1993).

Flood control and drainage projects, such as the Malaria Canal, the channelization of the Río Piedras River, and the relocation of the Bayamón River's outlet away from the estuary, along with the straightening and channelization of most of the remaining tributaries of the estuary, have caused considerable changes to the fresh water flow patterns in the estuary system. Stream peak discharges during the wet season have increased, fresh water flows are more pronounced and occur during a shorter period of time, and dry season discharges have diminished (Browder, *et al.*, 1989). Channelization of streams and the discharge of effluent from several flood control pump stations have concentrated discharges into specific areas, contrary to former natural conditions in which flow was dispersed along the estuary's wetlands.

Although the wind and especially the tides are the dominant mechanisms affecting water movement in the SJBE (Kennedy, *et al.*, 1996; Gómez-Gómez, 1993), the hydraulic system also is significantly affected by stormwater runoff. At least once each year, a rainfall event occurs which contributes sufficient runoff to replace the entire volume of water in the Piñones Lagoon and a considerable portion of the total water mass of the San José and La Torrecilla Lagoons (Gómez-Gómez, 1993). During substantial rain events, the combined volume of freshwater discharges received by the Suárez Canal and the San José, La Torrecilla, and Piñones Lagoons is enough to reverse tidal flows (Gómez-Gómez, *et al.*, 1983). Only extreme storm tides can create enough force to limit this outward flow. The combination of flows from the San José Lagoon and Blasina Canal forces La Torrecilla Lagoon to discharge as much as 95 percent of the total inflows to the lagoon out to the ocean (Gómez-Gómez, *et al.*, 1983). These effects are also observed at the junction of the Martín Peña Channel and the Puerto Nuevo River. Increased flow in the Puerto Nuevo River and the Martín Peña Channel from runoff and heavy pumping of storm drains during rainstorms creates a water current that overrides the incoming tide and produces an outward movement to the bay (Ellis and Gómez-Gómez, 1976).

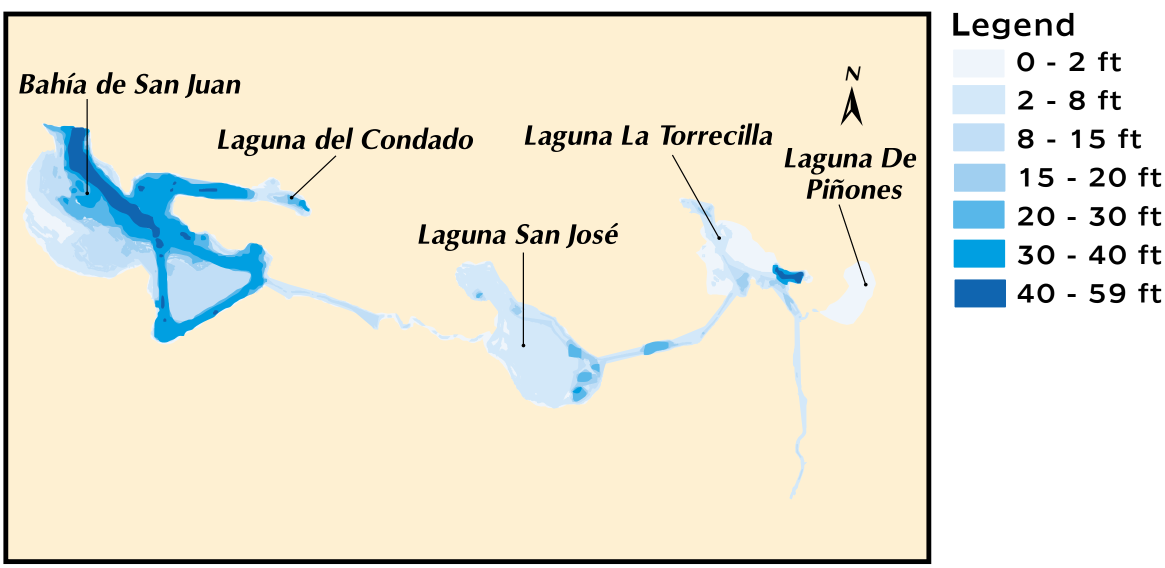
In contrast with the rest of the estuary, the Condado Lagoon and San Juan Bay are not considerably affected by fresh water inflows. Most of the time the flow is from the sea to the San Antonio Channel due to the Escambrón headland that deflects a westerly flowing ocean current into the mouth of the Condado Lagoon (Ellis, 1976; Ellis and Gómez-Gómez, 1976). The waves and swells increase this flow even more during heavy seas. The flow of water in San Juan Bay, with its deep and approximately 0.6 mile (0.9 km) wide outlet, is dominated by tidal exchange (Kennedy, *et al.*, 1996).

Puente Dos Hermanos, El Condado Lagoon.

The widening and deepening of the ocean outlets and the many estuary canals should have increased water conveyance both within the estuary system and between the estuary and the ocean (Keulegan, 1967; Gómez-Gómez, 1993). However, circulation in and out of the estuary is sluggish because the three outlets to the sea have small flow capacity compared to the total volume of the lagoons, and the maximum tidal range is less than three feet (1 m) (Ellis and Gómez-Gómez, 1976). The dredging of the lagoons has increased the time needed for the estuary to renew its waters since the system now stores a larger volume of water than it originally did. Although the construction of the Suárez Canal has helped to offset the restricted flow between the San José Lagoon and the ocean due to the obstructed Martín Peña Channel, it has not been enough to significantly increase water exchange. The old Highway 26 Bridge over the Suárez Canal constricts the flow in and out of the San José Lagoon (Ellis and Gómez-Gómez, 1976; Gómez-Gómez, *et al.*, 1983).

The SJBE Program recommends evaluating the feasibility of removing these flow constraints and this CCMP includes an action to fill the man-made depressions found in the estuarine system. Special emphasis has been given to the dredging of the eastern part of the Martín Peña Channel and to filling the deep dredged pits found in the Condado, San José, and La Torrecilla Lagoons and in the Suárez Canal. The SJBE Program is investigating several potential sources of fill materials for these dredged pits. Identifying these sources is part of the strategy for each proposed action that involves the filling of the depressions. Some of the potential sources being considered include: the Puerto Nuevo Flood Control Project, the dredging of the bay's navigational channels, and the widening and dredging projects being proposed for the Martín Peña Channel. Beneficial uses of dredged material, when feasible, could assist the SJBE Program in reaching the goal of improving water and sediment quality in these critical areas as well as the system as a whole. Through the use of a computer model, which simulated the currents and loadings in the SJBE, the impacts of various hydrodynamic and pollutant control enhancement alternatives were evaluated (USACE, 2000). From this exercise, a combination of actions that included filling the depressions to their historic depth, widening and deepening the Martín Peña Channel, and eliminating its sewage loads, were found to be the most cost-effective alternatives for improving the water and sediment quality of the system. See Figure 8, Water depths within the SJBE system.

Figure 8. Water depths within the SJBE system.



Habitat, Fish, and Wildlife

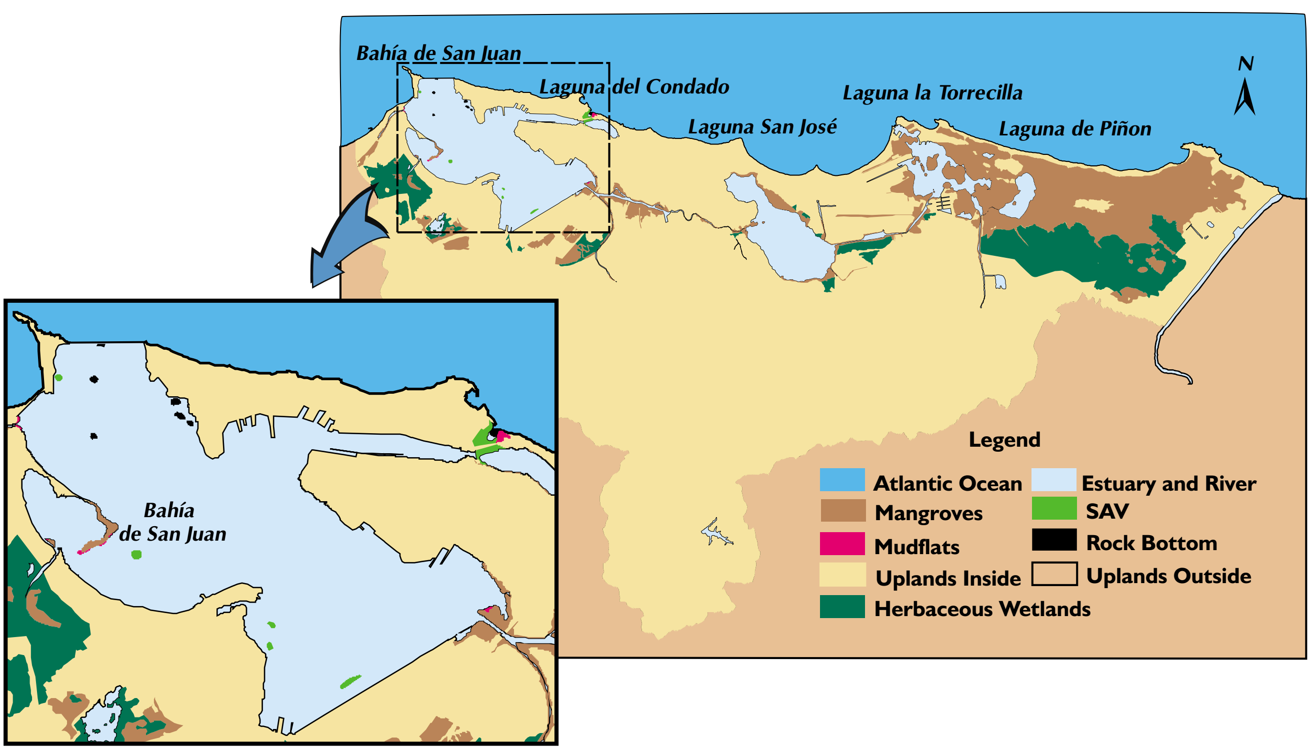
Between 1964 and 1990, the population in the San Juan Metropolitan Area increased by 87 percent. The estimated population of the Island of Puerto Rico is currently 3.9 million. Approximately 1.3 million people live in the San Juan Metropolitan Area, and 622,000 of these residents are in the SJBE drainage basin (based on 1990 estimates) (Puerto Rico Planning Board, 1998).

Development of the port and air traffic facilities, residential areas, and industrial complexes in the metropolitan area has resulted in modification and loss of some of the bay's important estuarine habitats. Dredging in the bay, lagoons, and canals has disturbed or destroyed a considerable portion of the habitats associated with the estuarine waters of the system. Filling of wetland areas has resulted in similar disturbances in mangrove and herbaceous habitats. Human modifications to the patterns and inflows of fresh water to the estuary have significantly affected the physical habitats and biological communities dependent upon these flows. In addition, a decline in system-wide water quality over the previous century has occurred, due to the urban development of the area and the behavior of its inhabitants (Coastal Environmental, Inc., 1997).

Most of the human modifications to the estuarine system have occurred in the western half of the area, where urban growth has been greatest. The eastern half of the estuarine system, although not pristine, is largely uninfluenced by these modifications to the west.

Mudflats, marshes, mangroves, submerged aquatic vegetation, coral communities, and sandy beaches are some of the types of habitats found within the SJBE system, supporting very rich and diverse biological communities. SJBE habitats and substrates are shown in Figure 9.

Figure 9. SJBE habitats and substrates.



Mudflats, Marshes, and Mangroves

Intertidal mudflats are comprised of areas of fine-grained sediments with no significant wetland vegetation coverage that are alternately inundated and exposed by the tide. Tidal floods and recessions across mudflats provide filter feeders with food and minerals. Mudflats are also prime feeding areas for birds. Until the late 1980s, the Constitution Bridge mudflats, which were located at the outlet of the Martín Peña Channel near San Juan Bay, were considered to have the most diverse and abundant bird population in Puerto Rico (relative to their size). These mudflats were destroyed by dredging for the Aqua-Expreso Ferry project. Although mitigation efforts included the creation of new mudflats to the north, by February 1996, these mudflats were removed by the Rio Puerto Nuevo Flood Control Project. Isolated mudflats still exist within the estuary, for example the site behind the sheet pile in the Martín Peña Channel and bordering mangroves along La Torrecilla and Piñones Lagoons.

Las Cucharillas Marsh at Cataño.

Herbaceous wetlands provide critical nursery habitat for a variety of fish and invertebrate species, as well as feeding and nesting areas for a high diversity of birds. Herbaceous wetlands are also an important component of nutrient cycles, and they stabilize and assimilate pollutants carried in runoff from upland urban areas. The main herbaceous wetlands within the SJBE system, where Cattail (*Typha dominguensis*) stands are the dominant species, are located in Las Cucharillas Marsh (west of San Juan Bay), in the Torrecilla Alta area, and on a smaller scale along the Suárez Canal (Coastal Environmental, Inc., 1997). Las Cucharillas Marsh contains approximately 500 acres (5 ha) of freshwater wetlands. Surrounding land uses include residential communities and storage/distribution facilities. A man-made, diked pond for the disposal of dredged material is located within the marsh near its southeastern corner. The areas in and around the marsh drain to the bay through the Malaria Canal. The importance of Las Cucharillas Marsh for flood protection for nearby communities and for water quality improvement matches its ecological values. For this reason, this Management Plan includes a specific action addressing the designation of Las Cucharillas Marsh as a Nature Reserve.

Mangroves provide feeding, breeding, nesting, and roosting areas for birds, mammals, and reptiles, with the vegetative detritus of mangroves serving as the base of the food web for crabs, mollusks, shrimp, and fish, among others. Mangrove stands in the more urbanized areas provide unique opportunities for biological communities dependent on the mangroves to survive and even thrive in the metropolitan area. The dominant vegetation within the mangrove community is red (*Rhizophora mangle*), black (*Avicennia germinans*), and white (*Laguncularia racemosa)* mangroves. In the southeastern region of the study area, within Torrecilla Alta, stands of swamp bloodwood trees (*Pterocarpus officinalis)* exist (Coastal Environmental, Inc., 1997).

Functions and Values of Wetlands

Water quality improvement. *Wetlands remove and absorb nutrients, process chemical and organic wastes or pollutants, and filter sediments from runoff.*

Water supply. *Wetlands act as rain and stormwater reservoirs and assist with groundwater recharge and discharge.*

Soil erosion. *Wetlands reduce soil erosion by slowing the speed of waters along rivers, streams, creeks, and swamps.*

Flood protection. *Wetlands absorb flood waters that overflow river banks as well as surface water runoff.*

Shoreline erosion control. *Wetland plants increase the durability of sediment and/or soil with their roots and dampen wave action.*

Wildlife habitat. *Wetlands provide habitat for many species of flora and fauna, including rare, threatened, and endangered species; these areas also provide corridors for movement and/or dispersal of wildlife.*

Fisheries. *Most commercial and game fish use coastal wetlands as nursery and/or spawning grounds.*

Recreation and aesthetics. *Wetlands offer a great variety of outdoor activities such as bird watching, scenic viewing, hiking, and boating for nearby communities and tourists. By serving as fish nurseries, they enhance sportfishing, snorkeling, and scuba diving.*

Air quality. *As in any other natural system comprised of plants, wetland plants help reduce air pollution, produce oxygen, and help to refresh the air.*

Noise reduction. *Wetlands, as well as other natural areas, serve as buffers for noise, especially when they are located in or near cities and urbanized areas.*

Scientific research and education. *Wetlands provide the opportunity for experimentation, observation, and practice in many fields of study.*

Note: Not all wetland types or specific wetland areas will serve the above-mentioned functions and values.

White-crowned pigeon (Columba leucocephala). *Courtesy of José Colón.*

Along with several isolated mangrove stands, the SJBE includes the largest mangrove forest of Puerto Rico, the Piñones State Forest Nature Reserve, with approximately 2,750 acres of mangroves. In an attempt to increase the number of acres of wetlands in the region, the Department of Natural and Environmental Resources (DNER) has directed efforts since the 1970s to designate the Torrecilla Alta-Vacía Talega area as part of the Forest. The SJBE Program recognizes the importance of this designation and addresses it in an action included in this Management Plan.

The temporal trends in emergent tidal wetlands in the SJBE system for the period of 1936 to 1995 are shown in Table 2. The trends indicate that while the San Juan Bay/Condado Lagoon, Martín Peña Channel, and San José Lagoon/Suárez Canal segments showed net losses in habitat coverage, the Torrecillas/Piñones segment showed a significant net gain of 391.7 hectares,

Table 2. Temporal trends in emergent tidal wetlands in the SJBE system by bay segment (hectares) for the period ca. 1936 to ca. 1995. (Source: Coastal Environmental, 1997.)

Bay Segment	Time Period	Mangrove Area (ha)	Marsh Area (ha)	Total (ha)
San Juan-Condado	1936	185.2	537.0	722.2
	1995	133.1	229.2	362.3
	Net Change %	-52.1 (-28.1%)	-307.8 (-57.3%)	-359.9 (-49.8%)
Martín Peña Channel	1936	416.3	234.0	650.3
	1995	138.4	38.4	176.8
	Net Change %	-277.9 (-66.8%)	-195.6 (-83.6%)	-473.5 (-72.8%)
San José-Suárez	1936	284.8	27.7	312.5
	1995	132.3	79.8	212.1
	Net Change %	-152.5 (-53.5%)	+52.1 (+288%)	-100.4 (-32.1%)
Torrecillas-Piñones	1936	1,129.1	770.5	1,899.6
	1995	1,845.9	445.4	2,291.3
	Net Change %	+716.8 (+61.2%)	-325.1 (-42.2%)	+391.7 (+20.6%)

or about 20.6 percent. However, this apparent "gain" in mangrove forest could be the result of a successional change from one type of habitat to another due to natural and/or human influences, such as meteorological events and land use modifications, and not necessarily due to habitat enhancement. It is also important to note that, by 1936, significant impacts to the wetlands of this area had already occurred due to the establishment of sugar cane plantations. The increase in wetland area corresponds to the natural regeneration process following abandonment of agricultural activities.

Submerged Aquatic Vegetation

Sea turtle grass (Thalassia testudinum). *Courtesy of USGS.*

Puerto Rico has one of the most diverse seagrass floras of the North Atlantic Ocean. Submerged aquatic vegetation (SAV) beds consisting of algae and seagrasses are documented to occur in San Juan Bay and the Condado and La Torrecilla Lagoons, although the boundaries and extent of these beds are presently under investigation by the National Marine Fisheries Service (NMFS). The estimated extent of these areas is shown in Table 3. Reported types of seagrasses in the SJBE include turtle grass, (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), sea wrack (*Halophila decipiens*), and shoal grass (*Halodule wrightii*) (Rivera-Herrera, 1996). The influence of seagrasses on coastal processes and their importance to mankind should not be overlooked. Seagrasses significantly modify the physical, chemical, and geological properties of coastal areas; they provide nutrients, primary energy, and habitats which sustain our coastal fisheries resources; and they provide foraging grounds for some endangered marine species (Vicente, 1990). Federally

Table 3. Water surface and bottom habitat area (hectares) estimates for San Juan Bay and Estuary Lagoons. (Source: Rivera, 2000).

Habitat	San Juan Bay (ha)	Condado Lagoon (ha)	San José Lagoon (ha)	Torrecilla Lagoon (ha)
Water surface area	1182.5	39.5	547	246
Mud area	1004.8	23.3	463.9	245
SAV area	12.5	14.0	0	.05
Algae area	15.2	0	0	1.0
Hard bottom area	150	2.2	0	0
Bivalve beds area	?	?	83.1	?

endangered species such as green sea turtles (*Chelonia mydas*) and West Indian manatees (*Trichechus manatus*) feed directly on seagrasses (Tetra Tech, Inc., 1992). Seagrass beds also serve as a substrate for epiphytes, such as filamentous algae and epiphytic diatoms, which in turn serve as food for invertebrates and fish.

Scarring by boat propellers is one of the impacts adversely affecting SAV beds in the estuary (José Rivera, NMFS, personal communication, 1999). Available data indicate that propeller scarring can last for many years. Turbulence caused by propellers and boat anchors can also adversely affect SAV and other benthic communities.

Recommended Habitat, Fish, and Wildlife actions in this Management Plan call for the restoration, protection, and enhancement of SAV within the SJBE system and its associated habitats once water quality improvements are achieved. Other recommended actions will also benefit SAV by enhancing water and sediment quality and other SAV-dependent variables.

Coral Communities

Coral communities and related habitats are found within the SJBE system at the San Juan Bay and Condado Lagoon outlets. The Condado Lagoon is the most diversified aquatic lagoon of the SJBE system. Coral communities and other invertebrates can be found in the lagoon together with a significant amount of SAV meadows and coral reef fishes. In addition, an area stretching along approximately 70 percent of the SJBE shoreline at a distance of 0.25 to 1 mile (0.4 to 1.6 km) offshore is composed of cemented sand dunes with coral communities. These various substrates, comprised of natural rock outcroppings, encrusted reefs, and calcified sand deposits, serve as habitats for a diverse assemblage of marine and estuarine fishes and invertebrates, some of which are valuable for recreational and commercial fishing. The living resources found in these areas are strongly dependent on the well-being of the estuary.

NMFS is using side scan sonar imagery to survey the benthic communities within the SJBE system. The benthic habitats identified to date include SAV and red algae beds, false mussel beds, hard bottom communities, bulkheads, pilings, mangrove prop roots, and possible bivalve beds, such as Mercenaria mercenaria *and* Macoma constricta.

Preliminary data indicate that the primary benthic species are polychaetes within San Juan Harbor, the false mussel Mytilopsis dominguensis *within the San José Lagoon, SAV (mainly* T. testudinum*) within the Condado Lagoon, and SAV and algal beds within La Torrecilla Lagoon.*

In spite of the fact that coral habitats in Puerto Rico have economic potential with regard to recreation and tourism, reefs have rapidly degraded during the last 25 years. Coral reef degradation is an issue of global concern that has become a priority at the international level. Water quality degradation, sedimentation, pollution, coastal development, overfishing, chaotic recreational utilization, and improper implementation and enforcement of coral reef management plans are some of the main factors which have led to the deterioration of coral reefs and related habitats in Puerto Rico (Beller, *et al.*, 1999).

To address the growing concern over the deterioration of coral reefs, Puerto Rico is participating at the international level in the Coral Reef Initiative Program. This program addresses the different actions needed to stop the degradation of coral reefs and associated habitats in Puerto Rico. In addition, at a local level, Law No. 147 of July 1999, known as the Coral Conservation Law, has been created to further protect corals and associated habitats, such as seagrasses and mangroves. Another local effort to enhance the marine ecosystem was the release of *Puerto Rico and the Sea* (Beller, *et al.,* 1999), a citizens' report to the Governor. The Living Resources and Coastal Zone chapters of the report address the important role that estuaries play in protecting coral resources and associated habitats and calls for the support of programs such as the SJBE Program (Beller, *et al.*, 1999).

It is expected that the implementation of actions that address improvements to water quality, reductions in sedimentation, and restoration of mangrove and SAV habitats, among others, will result in improvements to coral communities within and associated with the SJBE system.

Beach and Surf Zone

Piñones Coast, Loíza.

Sandy beach areas within the SJBE system are limited to the perimeter of La Esperanza Peninsula, the eastern shore of Isla de Cabras, La Puntilla, and the Condado Lagoon. Associated sandy beach areas of the SJBE system include, among others, the Condado area, Ocean Park, Isla Verde, Piñones, and Vacía Talega. The Condado and Isla Verde areas contain many hotels important to the tourism industry and one of the most frequented public beach sectors of the Island. The fauna of these zones are adapted to high wave energy environments, and include polychaete worms, bivalve mollusks, and crustaceans, most of which are visible at low tides. In addition, several species of fish prefer the environment characterized by the surf zone and shallow sandy bottoms of beach areas. Birds regularly visit the sandy beach habitats for feeding, and leatherback (*Dermochelys coriacea*) (FE), hawksbill (*Eretmochelys imbricata*), and green (*Chelonia mydas*) (FE) sea turtles utilize some of these habitats for nesting. Areas with nesting activity have been reported by the DNER in Isla de Cabras, old San Juan, Condado, Ocean Park, Isla Verde, and Piñones. Within United States jurisdiction, nesting activities of leatherback and hawksbill turtles occur principally in Puerto Rico and the USVI (NMFS and USFWS, 1992, 1993).

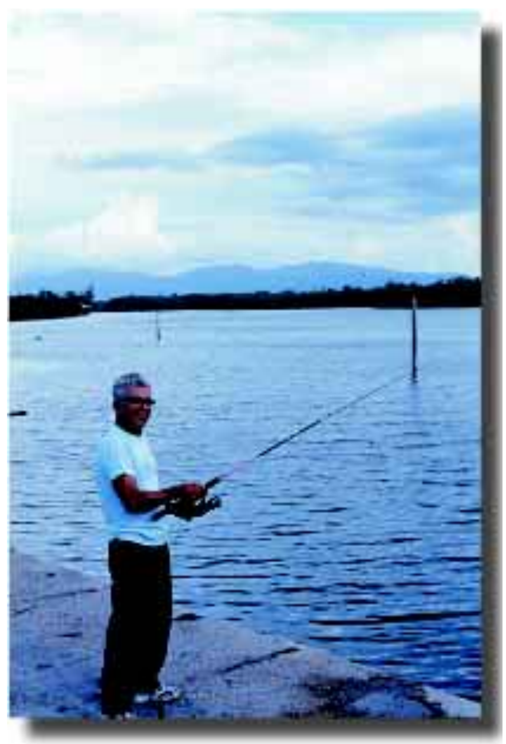
Human impacts to the nesting beaches associated with the SJBE system are high. Within the SJBE system, the most common documented threats to hawksbill turtles, and to a lesser extent leatherback turtles, are adult and egg poaching. Other threats, influenced by an increased human presence, and not yet quantified, include artificial lighting, artificial barriers, watercraft collision, ingestion of marine debris, and entanglement at sea. These threats may play a major role in determining the future population of these species (NMFS and USFWS, 1992, 1993).

The United States Fish and Wildlife Services (USFWS) and NMFS share the responsibility for the recovery of endangered sea turtles under the authority of the Endangered Species Act of 1973, as amended. Due to the critical status of some sea turtle species, NMFS and USFWS approved a Recovery Plan for Marine Turtles in 1984. The plan was developed to outline the recovery needs for the loggerhead (*Carettra caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*), and Kemp's ridley (*Lepidochelys kempi*) sea turtles (NMFS and USFWS, 1992, 1993). The main goal of the Recovery Plans is to delist species once various conditions are met. Conditions for recovery vary depending on the particular species. A joint effort between private enterprise, government, and the community is necessary for the species population to recover and be delisted. The USFWS is responsible for developing and implementing Recovery Plans for endangered species.

In an attempt to join this effort, this Management Plan includes an action concerning the implementation of the Recovery Plan for Sea Turtles. This action could be the first in a series concerning species within and associated with the SJBE system that are classified as critical or for which Recovery Plans already exist. The importance of Puerto Rico as a nesting area for leatherback and hawksbill sea turtles within the Caribbean region is clearly stated in the recovery plans. Implementation of recovery plans for these two species in Puerto Rico should contribute significantly to their overall recovery. The USFWS has been actively involved during the development and review of this CCMP, where actions are recommended that will complement the agency's goals.

Fishery Resources

Estuaries are invaluable natural systems for fishery resources. Mangrove and coral communities, seagrass beds, and mudflats associated with estuaries serve either as temporary or permanent habitats as well as nurseries and spawning grounds for adult and juvenile species of fish and invertebrates (Laegdsgaard and Johnson, 1995).



Local fisherman, Torrecilla Lagoon.

Within the SJBE system, with the exception of San Juan Bay, commercial fishing is prohibited by law. However, recreational fishing is allowed and enjoyed by many sportfishers, particularly in the areas of the San José Lagoon, Suárez Canal, and La Torrecilla Lagoon (Yoshiura and Lilyestrom, 1999). A creel survey in the San Jose and La Torrecilla Lagoons found that a significant number of fishermen from at least 14 towns use the SJBE for recreational fishing (Lilyestrom and Matos, 1997).

Studies of fish populations within the SJBE are limited, but at least 124 fish species have been identified (Rivera-Herrera, 1996; Yoshiura and Lilyestrom, 1999). Studies reveal that the top seven fish and shellfish species caught in the SJBE system are striped mojarra (*Diaperus plumieri*), common snook (*Centropomus undecimalis*), checkered puffer (*Sphoeroides testinudeus*), four teeth blue crab and two teeth blue crab (*Callinectes* and *Portunus* spp.), yellow fin mojarra (*Gerres cinereus*), and dog snapper (*Lutjanus joccu*).

In general, the fishery resources of Puerto Rico are showing the classic signs of overfishing – reduced total landings, declining catch per unit effort, shifts to catch smaller-sized individuals, and recruitment failures. A 69 percent reduction in fish landings has been reported for the period 1979-1990. In 1980, fish landings were estimated at 6.7 million pounds. Reported annual landings show a steady decline to 2.3 million pounds of fish in 1993. This reduction in fish landings is paired with a significant increase in fishing effort (number of gears and vessels) when comparing 1988 to 1995 (Sea Grant, 1995).

In addition to factors such as overfishing, improper law enforcement and a lack of knowledgeable enforcement agents contribute significantly to the present status of fishery resources. Obsolete fishing laws and regulations also have been problems. However, since 1997, in an effort to enhance fishery resources, the SJBE Program and DNER have been stressing the need for new laws and regulations. On November 11, 1998, a new bill was approved which revoked Law No. 83 and instituted more restrictive and protective fishery issues.

Little is known about the diversity and relative abundance of sport fishery resources in the SJBE system. The need for better data is highlighted in the recommended actions of this Management Plan. Action HW-17 addresses the need to identify fishing areas and primary targeted species as well as species abundance and establish fishery resource management plans if necessary. Other actions recommend enforcing current fisheries regulations and offering training to enforcement agents to enhance their knowledge of the SJBE system's resources and problems. It is important to note that implementation of these actions is strongly dependent on obtaining water and sediment quality improvements in the SJBE.

The SJBE system has been enjoyed for many years by sport fishers and could continue to be so enjoyed by present and future generations. As previously stated in the Water and Sediment Quality section, DNER and EQB published a Public Advisory warning in July 1999 on the potential health risks associated with consuming certain species of fish and blue crabs from specific areas of the SJBE system. Currently, USEPA is performing a second phase study on fish and blue crabs in order to gather further information on this potential health problem. Therefore, until this second phase study is completed, actions promoting recreational fishing in these areas should be put on hold.

Other Living Species

More than 160 species of birds, 124 species of fish, and 19 species of reptiles and amphibians have been reported within the limits of the SJBE system. Over 300 species of wetland plants, extending through coastal, aquatic, and marine habitats are found in the estuary. Habitat destruction, pollution, and other human-related disturbances are some of the main causes for the precarious status of many flora and fauna species within the SJBE system.

Four bird species are listed today as endangered: the brown pelican, the peregrine falcon, the snowy plover, and the endemic yellow-shouldered blackbird. Six others, such as the ruddy and masked duck, are listed as threatened (Rivera-Herrera, 1996).

Seventeen plant species have been identified as critical elements (meaning that they are rare, endemic, threatened, or endangered) (Coastal Environmental, Inc., 1997). These and other species classified as critical are listed in Table 4.

The SJBE also attracts the endangered West Indian manatee, a significant number of bottlenose dolphins, and the shortfin pilot whale (Mignucci-Giannoni, 1991). Numerous sightings of manatees have been documented within the SJBE system, including one siting inside the Puerto Nuevo River. In addition, an adult female manatee gave birth in October 1999 within the inner part of San Juan Bay, adjacent to the Guaynabo coastline. Manatee mortality is of primary concern since this species is considered the most endangered marine mammal in Puerto Rico (Mignucci-Giannoni, *et al.*, 2000). An action to determine the numbers and movement patterns of manatees and establish protection zones is included in this Management Plan. This action would generate useful information that could help in the overall recovery of this endangered species.

Mariquita de P.R. / Yellow-shouldered Blackbird (Agelaius xanthomus). *Courtesy of USFWS.*

Table 4. Critical elements (endemic, rare, threatened, or endangered plants and animals) in the SJBE watershed.

English Common Name	Spanish Common Name	Scientific Name
	Birds	
Brown Pelican	Pelícano pardo	*Pelecanus occidentalis*
Magnificent Frigate Bird	Tijerilla	*Fregatta magnificens*
Reddish Egret	Garza rojiza	*Egretta rufescens*
West Indian Whistling-Duck	Chiriría antillana	*Dendrocygna arborea*
Ruddy Duck	Pato chorizo	*Oxyura jamaicensis*
Masked Duck	Pato dominico	*Oxyura dominica*
Peregrine Falcon	Falcón peregrino	*Falco peregrinus*
Caribbean Coot	Gallinazo nativo	*Fulica caribaea*
Snowy Plover	Playero blanco	*Charadrius alexandrinus*
Roseate Tern	Palometa	*Sterna dougalli*
Least Tern	Gaviota chica	*Sterna antillarum*
White-crowned Pigeon	Paloma cabeciblanca	*Columba leucocephala*
Puerto Rican Emerald	Zumbadorcito de Puerto Rico	*Chlorostilbon maugaeus*
Puerto Rican Woodpecker	Carpintero de Puerto Rico	*Melanerpes portoricensis*
Puerto Rican Vireo	Julián Chiví	*Vireo latimeri*
Puerto Rican Striped-Headed Taneger	Reina mora de Puerto Rico	*Spindalis portoricenis*
Puerto Rican Bullfinch	Come ñame	*Loxigilla portoricensis*
Yellow-shouldered Blackbird	Mariquita de Puerto Rico	*Agelaius xanthomus*
	Amphibians, Reptiles, and Mammals	
Coqui	Coquí	*Eleutherodactylus coqui*
Leatherback Turtle	Tinglar	*Dermochelys coriacea*
Green Turtle	Peje blanco	*Chelonia mydas*
Hawksbill Turtle	Carey	*Eretmochelys imbricata*
Puerto Rican Boa	Boa de Puerto Rico	*Epicrates inornatus*
West Indian Manatee	Manatí	*Trichechus manatus*
	Plants	
Water Fern*	Helecho*	*Marsilea polycarpa*
Shrub*	Arbusto*	*Schoepfia arenaria*
Tree*	Uvero de monte	*Coccoloba sintenissii*
Sea-purslane	Herbácea suculenta	*Sesuvium maritimum*
Water-lily	Yerba acuática	*Nymphaea pulchella*
Gray nickers	Haba de San Antonio	*Caesalpinia bonduc*
Tree*	Cóbana negra	*Stahlia monosperma*
Herbaceous*	Cadillo anaranjado	*Pavonia paniculata*
Maga wood	Maga	*Thespesia grandiflora*
Tree*	Zapote de costa	*Manilkara pleeana*
Vine*	Bejuco*	*Aniseia martinicensis*
Herbaceous*	Herbácea*	*Hyptis spicigera*
Herbaceous*	Herbácea*	*Hyptis verticillata*
Intermediate Arrow-head	Herbácea rastrera	*Sagittaria intermedia*
Beakrush	Herbácea*	*Rhynchospora rufa*
Herbaceous*	Cortadora	*Scleria mitis*

* no common name exists

Aquatic Debris

A 1995 public perception poll sponsored by the Program indicated that residents are quite concerned about the presence of waste materials along the SJBE's waterways (Vega-Gerena, 1997). This debris can be attributed to inadequate solid waste management activities and several social and economic factors. Aquatic debris not only affects the aesthetic value of the estuarine system, but also poses health and environmental risks to all human, animal, and plant life within the ecosystem. Inadequate and illegal solid waste disposal practices lead to the presence of mosquitoes and other insects as well as unpleasant odors. The problem is most evident in the communities along the Martín Peña Channel, the San José Lagoon, the municipality of Cataño, and the area of Piñones, Loíza.

Large debris commonly found at Martín Peña Channel.

Types and Sources of Aquatic Debris

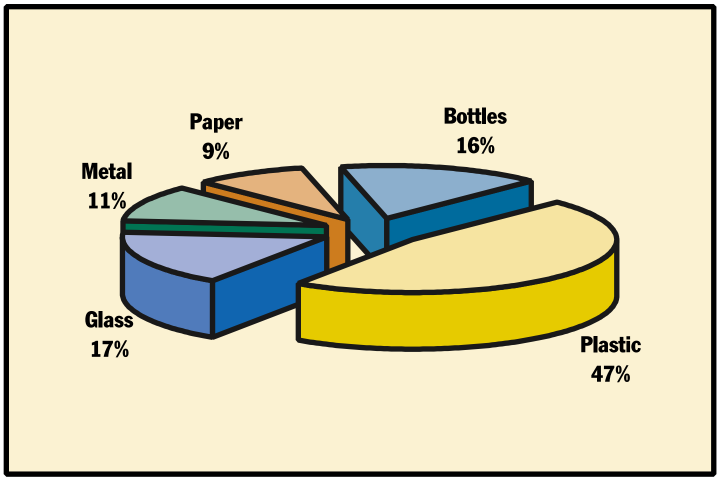
The main types of debris found along the shores of the SJBE are common household wastes (plastics, wood, glass, and paper), as well as discarded home appliances, tires, mattresses, furniture, and scrap automotive parts. Past coastal clean-up data, collected by SJBE area volunteers and analyzed by the Center for Marine Conservation (CMC), reveal that plastics, bottles, paper, glass, and metals are the most common waste items found in the estuary.

Most of the aquatic debris found in the SJBE comes from:

- Illegal dumping activities and trash left behind by shoreline visitors and residents;
- Waste generation and inappropriate disposal by communities and industries along the estuary's shorelines;
- Improper and inconsistent garbage collection practices by municipal governments;
- Litter carried by runoff into storm sewers and discharged into the estuary;
- Wastewater discharges; and
- Debris discarded or blown from vessels and offshore operations.

According to technical inspections from the Environmental Quality Board (EQB), the primary cause of aquatic debris in the SJBE area is individuals who litter and improperly dispose of their waste. However, the reasons behind these practices involve administrative, social, and economic issues.

Figure 10. San Juan Bay debris - most commonly found items (1986 - 1996).



The primary administrative issue is inadequate municipal garbage collection. Residential roads near the shoreline are not accessible to large waste collection vehicles. Therefore, these residences have not been incorporated into municipal garbage collection routes. Some of the residents choose to dump their trash directly into the estuarine system.

But the accumulation of aquatic debris in the SJBE system seems to be more than just a solid waste management problem. Social issues, such as land squatting and land reclamation activities, also result in trash entering the estuary. For example, some of the residents along the Martín Peña Channel and the San José Lagoon are illegally filling wetland areas with garbage to transform and reclaim the land on the waterway. These practices alter the natural shoreline and destroy important natural areas. Extensive filling has practically cut off the San José Lagoon from San Juan Bay.

An economic issue related to aquatic debris is the black market or underground economy that has formed for the disposal of wastes. Many illegal dumps filled with piles of construction materials and other debris can be found in abandoned areas around the estuary. These dump sites are created by individuals who are paid to collect and dispose of waste materials. By disposing of wastes illegally at clandestine sites at no cost, these individuals avoid the high costs of legal disposal in a municipal landfill. Illegal dumping is expected to get worse when the San Juan Municipal Landfill closes in the year 2000. This landfill currently charges approximately $80 per ton for dumping materials. Once it closes, disposal prices are expected to increase due to the cost associated with transportation to municipalities outside of the San Juan area.

Reducing Aquatic Debris in the Estuary

The EQB prepared a Solid Waste Enforcement Strategy (SWES) to help control the problem of solid wastes and aquatic debris within the SJBE. There are two primary approaches included in this strategy. The first one is to reduce, or preferably prevent, the flow of litter from its major sources into the system. The second is to remove the debris once it has entered the estuary through collection and pick up. Ultimately, the most effective strategy is to combat the root cause of the problem, which, in this case, is littering and improper disposal. Stopping debris "at the source" will require increasingly familiar activities such as litter control, recycling initiatives, and enforcement of existing laws. On the other hand, government actions such as regular garbage collection and disposal are equally important.

Based on the EQB's Solid Waste Enforcement Strategy, the Aquatic Debris Action Plan focuses on three main components to restore the ecological integrity of the SJBE: public involvement and education, voluntary compliance/solid waste pollution prevention, and enforcement. Proposed actions in these three areas address short-term solutions, such as periodic clean-up of aquatic debris in the estuary, as well as long-term solutions for solid waste prevention and enforcement tactics. The Cantera Peninsula Action Plan Demonstration Project (APDP) and the Piñones APDP are successful examples of the application of this three-tiered strategy. For example, through the Cantera Peninsula APDP, the community-owned recycling enterprise, known as People's Recycling Península de Cantera Inc., P.T., purchased two Cushman vehicles and two Ford pickups that would fit through the community's narrow alleys in order to collect and transport all recyclable materials generated in the community. People's Recycling conducts source reduction and waste recycling educational activities as well as clandestine dump vigilance. These successful initiatives target environmental impacts, but also improve the economic and social conditions of the community by providing numerous work and volunteer opportunities to community members. Similar initiatives should be developed and supported throughout the estuary to provide efficient solid waste management and recycling activities that reduce the amount of aquatic debris reaching the estuary and improve the quality of life in surrounding communities.

Household waste discarded at Martín Peña Channel.

Public Education and Involvement

The San Juan Bay Estuary's future rests in the hands of its citizens, leaders, and advocates who are the ultimate stakeholders in environmental protection. However, public understanding of this natural system is generally poor, resulting in a lack of broad support for necessary action (Vega-Gerena, 1997). A 1995 public opinion poll sponsored by the SJBE Program found a significant lack of knowledge about the estuary and its relationship to the public's quality of life. A vigorous long-term outreach and education program is needed to increase awareness of this natural system as well as citizen participation in its restoration and conservation.

Birdwatching at Cucharillas Marsh.

Citizens of every social, educational, cultural, and economic background live in the estuary drainage basin, from the scarcely populated Piñones to the densely packed residential and business conglomerates of the San Juan metropolitan area. Individual and community attitudes, therefore, are diverse and often differ, particularly on environmental and water quality issues related to the SJBE.

The nature and level of citizen interaction with the SJBE are varied. Some citizens frequently engage in recreational activities associated with the estuary such as sightseeing, swimming, surfing, fishing, kayaking, sailing, and jet skiing. The presence of four marinas (three on San Juan Bay and one on La Torrecilla Lagoon) and ten fishermen organizations (at San Juan Bay and the San José and La Torrecilla Lagoons) facilitate use of the estuary by yachters, boaters, and fishermen. These and other activities bring citizens in close contact with estuary waters (visually, physically, or through seafood consumption), where safe water quality is of critical importance for the public. In fact, public health risks, aesthetics, and decaying local economies (associated with the fishing and tourism industries) were identified as main concerns by a significant number of participants in the SJBE's 1995 public opinion poll.

At the community level, the nature of the interaction and use of the estuary system result in a different and more complex assortment of citizen interests and concerns. Rampant development in the San Juan metropolitan area since the 1930s left behind a vast array of low-income and middle class communities scattered along many of the estuary shorelines. Early migrants were pushed toward the growing cities as the inland agricultural economy declined. These early migrants settled on wetlands that, at the time, were considered to have no significant value. Five decades later, communities around the Martín Peña Channel, San José Lagoon, and Cataño areas face critical environmental conditions caused by sewage discharges, lack of appropriate infrastructure, storm drain pollutants, deforestation, the filling of wetlands, and illegal trash dumping. In these areas, citizen concerns go beyond aesthetics, health, and economic issues, to issues of ethics, public safety, and social, political, and environmental justice.

A number of community efforts have been initiated to address some of these environmental and social issues. Communities, such as Península de Cantera and Israel and Bitumul, located at the margins of the Martín Peña Channel, have identified safer housing for several hundred families. These families, currently inhabiting precarious structures and exposed to contaminated waters and other environmental hazards, will be moved to improved housing. These communities have developed highly successful programs that bring together local government and federal agencies, private enterprises, and religious groups to identify and secure alternative housing. The SJBE Program has fostered these community initiatives by providing information and soliciting the input of the affected communities. This public involvement and outreach has helped ensure that families to be relocated as part of the Water and Sediment Quality Action Plan (Action WS-2) are treated fairly and consistently and not exposed to disproportionate injuries as a result of the relocation process.

Specifically, the SJBE Program has continuously updated affected communities on the relocation process, distributed flyers to inform the community of meetings, provided opportunities for the public to ask questions and express concerns, and brought representatives from the involved agencies to the meetings. The SJBE Program has encouraged community members to request additional informative meetings if needed. (See Appendix J for a complete list of public involvement activities.) The Environmental Justice Coordinator at USEPA's Office of Water reviewed the SJBE Program's outreach and involvement efforts related to Action WS-2 of this CCMP and has found them to be satisfactory. The Environmental Justice Coordinator spoke with the Community Relations Coordinator of the Cantera Peninsula Project (CPP). The CPP Coordinator said the SJBE Program's public involvement and outreach efforts had been sensitive and respectful to the ethnicity, language, and culture of the communities. The CPP Coordinator also cited the need for additional community meetings, which the SJBE Program plans to conduct.

Stormdrain stenciling project at Condado.

The SJBE Program is supporting many other community efforts to enhance education, health, and the environment. The SJBE Program has delivered numerous presentations, focusing on themes such as water quality, natural resources management, and health in these communities. Demonstration projects conducted by the SJBE Program in Loíza, San Juan, and Cataño are providing further grounds to assist communities in these areas. Examples include:

- A solid waste management project in Loíza that has reduced solid wastes through recycling and, thus, promotes environmental quality improvements in the coastal community of Piñones.

- A series of presentations, home visits, and the request for installation of additional warning signs to assist the Península de Canteras Community in its efforts to educate the community regarding health risks associated with fish consumption in the San José Lagoon.
- A ten-week series of workshops on Las Cucharillas Marshland ecology — including sessions on community organizing and resource management, field trips to successful community projects, and environmental restoration activities within Las Cucharillas Marshland — that gave participants a clearer perspective of their common vision and how they could achieve it.

The residents of Cataño and Piñones are actively engaged in the conservation and sustainable development of some of the most critical natural habitats of the SJBE. These communities are interested not only in improving their quality of life and social justice, but also in the survival of their unique and endangered cultural heritage. For example, several business establishments in Piñones have engaged in a solid waste management and recycling program through a SJBE Program APDP. This project contributes to the conservation of the marine environment by reducing and better managing all of the wastes generated in the area in order to reduce the amount of debris that reaches the beach and eventually the ocean.

Other communities, throughout the highest slopes of the SJBE basin, such as Caimito, and San Patricio in the lower slopes, are more concerned with the protection of the estuary's watershed and tributaries, where deforestation, soil runoff, erosion, sedimentation, channelization, and other consequences of urban development are seriously impacting their environment and quality of life. Through their own initiative, many of these communities are undergoing an intense environmental and social reconstruction process, the main objectives of which are in harmony with the SJBE Program's primary goals.

The commercial and industrial sectors have predominantly economic interests regarding the use of the estuary. Access to the San Juan Bay waters is important for commercial port facilities and industrial related processes. Aesthetics are also important to the commercial sector to promote recreation and tourism.

"Parque Lineal Enrique Martí Coll" at Martín Peña Channel.

As revealed in the 1995 public opinion poll and indicated by the degree of group activism from communities, environmentalists, special interest groups, academics, and others, most citizens are aware of existing environmental problems. Yet, these same citizens have virtually no sense of their relationship to the SJBE natural system. Understanding the various citizen concerns, as well as the commercial, industrial, and governmental interests, and informing all of these stakeholders about their interrelationships with the SJBE natural system are essential ingredients in the design of an effective public outreach and education strategy for the estuary.

The objectives of the initial SJBE Public Education and Outreach Program were to raise the awareness needed to recruit citizen support in the restoration and conservation of the estuary and to encourage active participation in the development of the Management Plan. The growing support for the SJBE Program and increased public and media interest in SJBE issues experienced in the last few years are indicators of the effectiveness of these efforts. In working toward Management Plan implementation, the SJBE Program's Public Education and Outreach strategy will promote actions to ensure and encourage long-term citizen awareness and stewardship in the restoration and conservation of the estuary. Developed strategies provide the grounds for involving industry and business in this process.

Actions in this Management Plan focus on: 1) sustaining past educational efforts to target all interest groups within the SJBE, 2) facilitating and encouraging active citizen and community participation in the implementation of action plans, and 3) promoting sustainable use of the SJBE's natural habitats as educational, recreational, and ecotourism resources.

Introduction to Action Plans

During the Management Plan development process, the San Juan Bay Estuary (SJBE) Program encouraged communication and consensus-building among diverse interest groups to prioritize issues of concern and develop proposed solutions to improve the health of the estuary. Where consensus was not reached, decisions were made based on a majority vote. Chapters 3 through 6 of this document present the recommendations of the technical community, local governments, state and federal agencies, and concerned residents and users of the estuary and its watershed through 49 actions within a series of four Action Plans:

- Water and Sediment Quality
- Habitat, Fish, and Wildlife
- Aquatic Debris
- Public Education and Involvement

These four chapters provide information on why the actions are necessary and describe how the actions will be accomplished. Each of the 49 actions is considered essential to accomplish the goals of the CCMP; however, the Management Conference has given a priority ranking to each action as follows: "urgent", "important", or "needed" (see Appendix H).

"Urgent" actions deserve immediate attention and should be initiated as soon as possible or within 0-5 years after CCMP approval.

"Important" actions have significant value to the estuary or address potentially adverse conditions, such that they should be initiated within 5-10 years after CCMP approval.

"Needed" actions are either required, deemed necessary, or have an obligation to be initiated within 10-15 years after CCMP approval.

The Management Conference identified 9 actions as high priority or "urgent", and they are marked with a (!) next to the action title. The draft CCMP included a larger number of "urgent" actions; however the SJBE Program Management Conference reassessed priorities and redefined the Program's focus following the public review process.

The members of the Management Conference considered the following criteria in selecting high priority or "urgent" actions:

- The action is technically feasible, sustainable, and will have a measurable positive effect (in the short- or long-term) with respect to its objective.
- The action demonstrates immediate action, rather than ongoing research or data collection (although such comparison must be based on wider considerations).
- The action is generally acceptable with the potential of having wide community support.
- The action is cost-effective, both in start-up costs and long-term maintenance and operation.

To help track and ensure implementation, the Management and Policy Committees identified each action as either a commitment or recommendation. (See Tables 6 through 9 at the end of Chapter 7). These terms are defined as follows:

- Commitment – a pledge or engagement which assumes an obligation to undertake all needed actions to ensure the assignment of funds and the implementation of the urgent actions and other actions marked with a "C" in Tables 6 through 9 of this CCMP.
- Recommendation – an action that is worthy of implementation due to the resulting improvement on the estuary's functions and values but for which funds are not readily available or its implementation is not urgent.

There is a general commitment by the Management Conference to actively seek funding to enable the implementation of every action in the CCMP.

Key to Actions

Each action includes the following information:

Background

Key findings from completed and ongoing research efforts; justification for the action. In addition, when appropriate, information on APDPs has been included here.

Strategy

A list of the steps required to implement the action. Included in the strategy is information on implementing partners, the schedule for implementation, cost, and location of the action.

Implementing partners are identified for each step needed for action implementation. Implementing partners include agencies, municipalities, or other entities as established by law or by consensus. These could also include entities from which permits, endorsements, support, or another type of involvement is necessary for action implementation. A lead(s) partner is identified for each step.

For steps where there is already a commitment by an implementing partner, or where a step has been completed, a specific date for implementation is provided. However, in most cases, the actions have not been formally scheduled and will be dependent on securing commitments from implementing partners. Tables 6 through 9 in Chapter 7 identify potential funding sources and commitments for each action. For most actions, schedules are presented for each step as short-term, mid-term, or long-term. The phrase short-term means that implementation should start within 0-5 years of Management Plan approval; the phrase mid-term means that implementation should start within 5-10 years of Management Plan approval; and the phrase long-term means that implementation should start within 10-15 years of Management Plan approval.

A best estimate of projected costs is provided for each action. In some cases, due to the nature of the action, for example if the full extent of the action can not be determined, total costs have not been estimated, but unit costs are provided. Table 12 indicates which CCMP actions have been incorporated into lead partner implementation plans or are supported by these plans.

Expected Benefits

The benefits to the estuary system and its residents that are anticipated with implementation of the action. Measures of success by which future progress can be gauged.

Monitoring Environmental Response/Programmatic Implementation

A brief overview of the key monitoring activities called for in the *Monitoring Plan* (Volume II), which is available from the SJBE Program Office. The *Monitoring Plan* outlines the approach to monitor action implementation and measure environmental results through sampling and analyzing water quality and other activities.

Regulatory Needs

Any new regulation, legislation, or administrative course of action that will be needed for action implementation.

Action Summary Tables

Appendix H contains a summary table for each of the four Action Plans. Appendix I organizes actions by implementing partner.

Maps

For certain actions, maps are provided that show the approximate area where the proposed action will take place (identified by the word "AREA" on the map). These maps may be found in Appendix A of this CCMP.