SUBREGION 10:
CALOOSAHATCHEE RIVER BASIN AND SOUTHWEST FLORIDA

INTRODUCTION

Subregion 10 encompasses the Caloosahatchee River watershed, the lower Charlotte Harbor estuarine ecosystem and coastal system south to Naples Bay, the Corkscrew Regional Ecosystem Watershed, and the Immokalee Rise. The subregion includes Lee County, western Collier and Hendry counties, southern Glades County, and southeastern Charlotte County (Figure 1).

This chapter summarizes the major ecological and hydrological issues, problems, and threats in Subregion 10; existing scientific information on these topics; and ongoing and proposed science projects. It identifies scientific information gaps and the studies needed to fill these gaps. The purpose of this task, and the Science Subgroup, is to provide the necessary scientific information to develop and implement management strategies to restore impacted ecosystems to a naturally functioning, self-sustaining state and to prevent further ecosystem degradation. The task was accomplished by meeting with scientists who work in this subregion and reviewing the scientific literature.

BACKGROUND

As occurs in most of Florida, the human population in Subregion 10 is concentrated along the coast, which is rapidly becoming highly urbanized. This coastal zone had the highest growth rate in Florida over the last 10 years and has the highest projected growth rate from now to 2010. The Cape Coral-Fort Myers and Naples metropolitan areas are among the seven fastest growing in the U.S. In the 1980s, Collier and Lee County populations grew by 77% and 63%, respectively (SFWMD 1992). Projected population increases for Collier and Lee Counties from 1990-2010 are 140% and 90%, respectively (SFWMD 1992).

A somewhat unique aspect of this subregion is large-scale "planned" residential development projects, which were constructed from the late 1950s to the early 1970s. Cape Coral, Lehigh Acres, and Golden Gate Estates are the largest of these developments. Cape Coral is the second largest Florida city in area (285 km$^2$: 110 mi$^2$). The natural habitats in over 90% of this area were destroyed; wetlands were filled and terrestrial forests were cleared of vegetation. Over 2000 km (1242 mi) of roads and 650 km (404 mi) of freshwater and estuarine residential canals were constructed. During this process most of the land was platted and sold as residential home sites. The projected build-out population of Cape Coral is 400,000 people. Population today is 80,000-100,000. Many areas of the city are sparsely populated; however, Cape Coral is one of the five fastest growing cities in the country. The environmental impacts of such "mega" developments are discussed below.

Agriculture is a major land use in the interior of Subregion 10. This subregion probably has the State's highest rate of land conversion to agriculture, primarily citrus. In the 1980s, irrigated agricultural acreage in Collier and Lee Counties increased by 99% and 35%, respectively (SFWMD 1992). From 1984-1994, citrus acreage in Southwest Florida (Lee, Collier, Hendry, Glades, and Charlotte Counties) grew from 17,000 ha (42,000 acres) to 72,000 ha (178,000 acres), an increase of 320% (FASS 1994). This boom in acreage is the result of interregional movement of citrus farming from Central to Southwest Florida following several severe freezes in the mid-1980s. Projected increases in citrus acreage for Collier, Hendry, Glades, and Lee counties from 1990-2010 are 150%, 100%, 90%, and 50%, respectively (SFWMD 1992). Environmental implications of this conversion are discussed below.
Caloosahatchee River Watershed

The river basin drains an area of about 3700 km$^2$ (1429 mi$^2$). The basin extends from Lake Okeechobee to the river mouth in San Carlos Bay. The watershed includes northern Lee and Hendry Counties, southern Glades County, and southeastern Charlotte County.

The Caloosahatchee River was originally a shallow meandering stream about 80 km (50 mi) long with headwaters near Lake Hicpochee (Drew and Schomer 1984; Hammett 1990). The river was extended east to Lake Okeechobee by dredging in 1884, and it was first channelized to improve navigation and flood control in the 1930s. Three locks or water control structures were constructed on the river: Moore Haven Lock and Ortona Lock in 1937, and Franklin Lock, near Olga, in the 1960s. Franklin Lock acts as a salinity barrier. The freshwater portion of the river is 60 km (37 mi) long; the tidal Caloosahatchee extends downstream of Franklin Lock for about 45 km (28 mi). Most of the freshwater entering the Caloosahatchee estuary is through Franklin Lock. There are 60 tributaries to the Caloosahatchee River; many are channelized.

The most common land uses in the freshwater portion of the basin are agriculture and rangeland; the tidal basin is primarily urbanized.

Charlotte Harbor Estuarine Ecosystem

The Charlotte Harbor estuarine system includes Charlotte Harbor proper; Pine Island Sound; Matlacha Pass; San Carlos Bay; an extensive barrier island system; and the tidal reaches of the Caloosahatchee, Peace, and Myakka Rivers. The estuary is the second largest in Florida with a surface area of 700 km$^2$ (270 mi$^2$). The watershed is about 12,140 km$^2$ (4687 mi$^2$) (Hammett 1990). There are five NWRs, four State aquatic preserves, and two State land preserves within the system. Only the southern half of the system is in the SFWMD and technically part of Subregion 10; the northern half is in the SWFWMD. Management implications of this political division are discussed below.

The system is a shallow, subtropical, coastal plain estuary with an overall mean depth of about 2 m (6.6 ft). Water depths in the northern portion are 0.5-1 m (1.6-3.3 ft) greater than the southern. The estuary is separated from the Gulf of Mexico by a series of large barrier islands. Total average discharges to Charlotte Harbor from the Caloosahatchee, Peace, and Myakka rivers are 2000 cfs, 2000 cfs, and 630 cfs, respectively (Hammett 1990). Direct rainfall contributes about 1000 cfs. The water column is usually partially to thoroughly mixed due to the shallow depths and moderate freshwater inflows (SWFWMD 1993).

Seagrass and benthic macroalgae are abundant in Pine Island Sound and Matlacha Pass. Deeper Charlotte Harbor proper has fewer benthic macrophytes and primary productivity is plankton based. The system provides habitat for over 30 threatened or endangered species and supports highly productive fisheries.

Estero Bay Estuary and Watershed

This system in southwestern Lee County consists of Estero Bay and associated barrier islands, the Estero Bay basin including the Imperial and Estero Rivers, and the Six Mile Cypress Slough Watershed.

Estero Bay is a shallow, subtropical lagoon (4580 ha; 11,317 acres) separated from the Gulf by barrier islands. Seagrass beds are common in the bay, but high turbidity restricts seagrasses to shallow depths (Lee County 1994). Estero Bay differs from Charlotte Harbor in that there are no significant rivers flowing into it and only weak tidal exchange due to restricted inlets (Godschalk and Assoc. 1988). Lands surrounding Estero Bay, including the barrier islands, are highly developed. Estero Bay is a State aquatic preserve.

Six Mile Cypress Slough (830 ha; 2050 acres) is characterized by dense cypress interspersed with numerous ponds. The slough has been preserved through Florida's SOR Program (SFWMD 1993a).
**Corkscrew Regional Ecosystem Watershed**

The CREW is 23,500 ha (58,069 acres) of mostly functional wetlands in southeast Lee and north Collier Counties. The watershed contains a variety of habitat types and plant communities, the most common being cypress sloughs (CREW Trust 1992). The 4460-ha (11,021-acre) Corkscrew Swamp Sanctuary, operated by NAS, is part of this watershed. The Sanctuary has North America's largest nesting colony of endangered wood storks and largest remaining stand of virgin bald cypress (Duever et al. 1974; Browder 1984). The CREW provides habitat for about 75 endangered or threatened plant and animal species (CREW Trust 1992).

The CREW has significant hydrologic importance to the region. It conveys water to Florida Panther NWR, Fakahatchee Strand State Preserve, and the Estero Bay State Aquatic Preserve Watershed. The CREW is on the approved projects acquisition lists of the State SOR and CARL programs. Since 1989, 5670 ha (14,010 acres) have been acquired (CREW Trust 1992). Most of the land surrounding the CREW has been converted to agriculture (Immokalee Rise agricultural area). Winter vegetables are the primary crop, but citrus is increasing.

**Hydric Pine Flatwoods**

The hydric pine flatwoods ecosystem is characterized by a slash pine-dominated (*Pinus elliottii*) upperstory and wetland plant understory (Beever and Dryden 1993). The longer hydroperiod and wetland understory differentiate this ecosystem from xeric and mesic pine flatwoods. Only recently have scientists and government regulatory agencies recognized hydric pine flatwoods as a separate community or ecosystem type. Hydric pine flatwoods covered at least 81,000 ha (200,151 acres) in Southwest Florida in 1989 (Beever and Dryden 1993). This ecosystem type also occurs in Subregion 3 (in Martin and Palm Beach counties).

The hydric pine flatwoods of Southwest Florida have regionally significant ecological and hydrological value. Plant species diversity is high: over 900 species, including 85 protected species (Beever and Dryden 1993). At least 21 Federal and State listed animal species utilize this ecosystem. Hydric pinelands are thought to be important to groundwater recharge (Beever and Dryden 1993).

**MAJOR ISSUES**

**Alteration of Natural Freshwater Inflow to Estuaries**

As elsewhere in South Florida, the natural pattern (quantity and timing) of freshwater inflow to estuarine ecosystems in this subregion has been altered by anthropogenic activities. These activities include channelization and water control structures for flood control, dredging for navigation, wetland drainage and filling, and urban and agricultural land development.

**Caloosahatchee Estuary**

The natural pattern (quantity and timing) of freshwater flow into the Caloosahatchee estuary has been disrupted due to its unnatural connection to Lake Okeechobee, water control structures on the river, the network of channelized tributaries and drainage canals in the basin, and urban and agricultural water demands (Drew and Schomer 1984; Hammett 1990; SFWMD 1993b). Periodic regulatory releases from Lake Okeechobee are made to the estuary via the river. During such releases the volume of freshwater entering the estuary can be >10,000 cfs (SFWMD 1993b). These releases usually occur during the latter part of the dry season when freshwater inflow would naturally be lowest. Because of these discharges the freshwater flow into the estuary exceeds the historical volume, especially in the dry season. Conversely, when regulatory discharges are not occurring, unnaturally low freshwater inflow can occur during the dry season due to high water demand for agricultural and urban uses (SFWMD 1993b). The network of channelized tributaries and drainage canals exacerbates the excessive discharge problem.

Several studies indicate this altered flow pattern impacts the Caloosahatchee Estuary. Discharges >6000 cfs from Franklin Lock cause the entire estuary to become oligohaline and can decrease salinity in the outer...

**Spreader Waterways and Cape Coral**

The concept of "spreader waterway" was developed as a mitigation technique to reestablish sheetflow of water in wetlands that are anthropogenically altered. Spreader systems seem most common in Southwest Florida. The largest system, with 40 km (25 mi) of spreader waterways, is in Cape Coral.

The condition and function of the Cape Coral spreader system was recently evaluated (Morrison et al. 1990). Construction of the 650-km (404-mi) Cape Coral residential canal system altered the natural freshwater sheetflow pattern into Matlacha Pass (Charlotte Harbor). Two spreader waterways were constructed to reestablish sheetflow in the late 1970s. The spreader system is not functioning properly (Morrison et al. 1990). There are numerous breaches resulting in channelized freshwater flow into Matlacha Pass. This channelized inflow has eliminated or degraded seagrass and mangrove habitat and reduced seagrass productivity. Dysfunctional spreader systems, such as that at Cape Coral, make the effectiveness of this mitigation method questionable.

**Faka Union Bay and Golden Gate Estates**

Construction of the Faka Union and Golden Gate Estates canal systems altered natural freshwater sheetflow into Faka Union Bay and adjacent estuarine areas (Browder et al. 1989; SFWMD 1994). The canal systems increase the rate of surface water runoff, resulting in substantial point loads of freshwater into the estuaries. This alteration has had the following effects on the estuarine ecosystem: altered natural salinity regime and freshwater shocks; decreased nursery value for fish and shellfish by reducing the area with salinity ranges favorable for planktonic and juvenile forms; reduced abundances of subadult and adult fish; increased nutrient loading; and long-term negative effects on habitat quantity and quality, including likely decline in seagrass coverage (Browder et al 1989; SFWMD 1994).

**Charlotte Harbor Estuarine Ecosystem**

The environmental quality of Charlotte Harbor is generally considered to be better than most Florida estuaries. Significant habitat loss and water quality degradation, however, have occurred over the last 30-50 years.

Seagrass and saltmarsh acreage decreased 29% (99 km²; 38 mi²) and 51%, respectively, from 1945-1982 (Harris et al. 1983). However, mangrove forest acreage appears to have increased 10% during this period. Additional seagrass and saline marsh loss and alteration occurred from 1982-1990 (Morrison et al. 1990; R. Repenning, FDEP, pers. comm.; L. Riley, Lee Co., pers. comm.). Submerged vegetation in the lower Caloosahatchee estuary has decreased significantly since installation of Franklin Lock (SFWMD 1993b). These losses are attributed to anthropogenic activities, especially large land development projects, causeway construction, and alteration of freshwater inflow patterns.

Nutrient loads, especially nitrogen, entering the estuary have been increasing for the past 15-20 years. Nitrogen and phosphorus inputs via the Caloosahatchee River and nitrogen input from the Peace River have risen (McPherson and Miller 1990; Hammett 1990). Increased urban, especially wastewater treatment plants, and agricultural development account for the greater nutrient loading. Furthermore, urban growth alone is predicted to enlarge nitrogen loading by 20% by the year 2020 (Hammett 1990). Primary production in the estuary appears to be nitrogen limited (Montgomery et al. 1991; McPherson and Miller 1990). The projected increased nitrogen loads favor undesirable growth of phytoplankton and benthic algae (McPherson and Miller 1990).

Turbidity has probably increased in lower Charlotte Harbor due to alteration of the estuary bed from dredge-fill activities and seagrass loss (Harris et al. 1983). Suspended, nonchlorophyll particulate matter is the primary cause of water column irradiance attenuation in the estuary (McPherson and Miller 1987). Thus, light reaching benthic vegetation has likely decreased in recent years. Irradiance may limit benthic vegetation growth in parts of the
estuary, especially deeper water (McPherson and Miller 1987). Predicted greater phytoplankton density with increased nitrogen loading would further decrease irradiance and inhibit seagrass growth.

Mosquito pesticide application (aerial spraying) is conducted extensively in the Charlotte Harbor system. Lee County has one of the largest mosquito control programs in the country. There is concern and debate about potential ecological impacts of mosquito pesticide application in the mangrove ecosystem. Temephos (Abate), a larvicide, is used in the estuary, including the NWRs. Temephos can be toxic to aquatic invertebrates, especially crustaceans (Clark 1991). However, Pierce et al. (1989) did not observe acute toxicity to five species of crustaceans and fish exposed to a field application of temephos in Charlotte Harbor. Temephos can persist for several days (Clark 1991). FDEP does not permit temephos application on designated aquatic preserves in Charlotte Harbor. The FWS has recently ordered Lee County Mosquito Control to cease spraying temephos on NWRs. Fenthion (Baytex), an adulticide, is also used in Lee County around Charlotte Harbor. It is very toxic to marine invertebrates (Clark 1991). There is concern about drift of fenthion into mangroves. Faunal mortalities in State aquatic preserves may have been caused by fenthion drift (B. Repenning, FDEP, pers. comm.). The aquatic half-life of fenthion is 4-7 days (Clark 1991). No field studies on chronic or sublethal effects of fenthion have been conducted (Clark 1991).

Low DO levels, high chlorophyll \( a \) concentrations, and high sediment metal concentrations have been reported in the tidal Caloosahatchee (DeGrove and Nearhoof 1987; SFWMD 1993b). However, water quality data for the tidal Caloosahatchee are insufficient for temporal analysis (DeGrove and Nearhoof 1987).

The numerous residential canal systems that feed into the estuary likely contribute to estuarine water quality degradation. For example, the 250-km (155-mi) estuarine portion of the Cape Coral canal network has significantly poorer environmental quality (lower DO and benthic invertebrates; higher nutrients, sediment metals, and turbidity) than the Caloosahatchee estuary (Morrison 1989).

**Freshwater Caloosahatchee River**

The freshwater Caloosahatchee is a severely stressed ecosystem, with substantial water quality problems. State water quality standards have been frequently exceeded (DeGrove and Nearhoof 1987). Water quality problems include: low DO; high nutrients (total nitrogen usually >1.5 mg/L, total phosphorus usually >0.1 mg/L); high chlorophyll \( a \) and undesirable algal blooms; high water column pesticide and metal concentrations; and high metal levels in sediment and invertebrates (DeGrove and Nearhoof 1987; J. Cassani et al., Lee County, unpublished data). Specific conductance increased and ionic composition changed between the 1940s and 1980 (LaRose and McPherson 1983). Lake Okeechobee discharge and basin runoff contribute pollutants to the river; however, there is conflicting information on which source most affects river water quality (CDM 1991a).

**Estero Bay Estuary and Watershed**

Water quality in Estero Bay is generally considered to be fair to good; however, degradation has occurred in recent years (Godschalk and Assoc. 1988; Lee Co. 1994). Nutrient and turbidity levels have increased. Estero Bay sediments are enriched in cadmium, lead, and zinc. The freshwater inflow pattern has been altered. Water quality problems are attributed to increased urbanization of the watershed and, for turbidity, increased boat traffic. Watershed urbanization was projected to increase by over 130% (based on number of dwelling units) from 1986-2010 (Godschalk and Assoc. 1988). Environmental quality in Estero Bay is particularly vulnerable to future degradation due to poor flushing, the bay’s low volume, and increasing urbanization of the watershed (Godschalk and Assoc. 1988).

The natural hydroperiod and water flow pattern in Six Mile Cypress Slough has been altered (Lee Co./SFWMD 1988; SFWMD 1993a). Exotic plant invasion is a problem (SFWMD 1993a; Lee Co. 1994). The southern third of the slough is heavily infested with melaleuca (*Melaleucaquinquenervia*); exotic control and reforestation efforts are ongoing in the slough.
**Citrus Development and Other Agricultural Issues**

As discussed above, there has been and will continue to be considerable conversion of uplands and pasture lands in Subregion 10 to citrus. Much of the current and proposed citrus development occurs in an area with diverse fauna and flora, including 31 Federal and State protected species (Mazzotti et al. 1992), and adjacent to valuable wetlands. There is concern about potential effects of citrus development on plants, wildlife, and their habitats and on surface and groundwater quality and quantity. For example, some citrus development projections estimate that up to 50% of available habitat for the endangered Florida panther in the Immokalee Rise area may be lost (Mazzotti et al. 1992). However, there are few studies that evaluate possible impacts.

Citrus has lower biological habitat value than pasture, upland, and wetlands -- the habitats most likely to be converted to citrus. Most species occurring in citrus groves inhabit agricultural reservoirs, temporary ponds, or seasonal wetlands in groves. In addition to habitat loss, another consequence of citrus conversion is fragmentation of remaining high-quality habitat (Mazzotti et al. 1992). Mazzotti et al. (1992) developed and evaluated alternatives for integrating biological conservation and citrus development in Southwest Florida.

Agriculture dominates water use in the interior of Subregion 10 (SFWMD 1992). Citrus uses more water per acre than any other type of agriculture, except plant nurseries (Hammett 1990). More water use permits are issued for citrus than any other agricultural type (Mazzotti et al. 1992). From 1990-2010, water demand by citrus in Collier, Glades, Hendry, and Lee Counties is projected to increase 130%, 80%, 70%, and 35%, respectively. Citrus farming causes lower water tables, which impacts hydrology and the structure and function of wetlands (SFWMD 1992).

Employing BMPs will likely reduce pollutant export via surface runoff from citrus groves. Greater than 95% of nutrients and 99% of pesticides applied to a grove with wet detention systems were retained on site (Sawka et al. 1994).

**Corkscrew Regional Ecosystem Watershed**

All lands around the CREW are undergoing intense development pressure from agriculture and other land uses (CREW Trust 1992). Much of the surrounding land has been converted to agriculture, mainly vegetables but more recently citrus. The ecological and hydrological effects on the CREW are not known.

Two municipal wellfields have cones of influence that extend into the CREW (CREW Trust 1992). There is concern that these wellfields are lowering groundwater and surface water in CREW wetlands, affecting wetland hydrology and ecology. A SFWMD contract study is evaluating the potential impacts of wellfield withdrawal (CREW Trust 1992).

Pine flatwoods in parts of the CREW were clear cut in 1989-90 for conversion to citrus. However, SFWMD has acquired this land, and natural reforestation is taking place (CREW Trust 1992). Invasive exotic plants, especially melaleuca and Brazilian pepper (*Schinus terebinthifolius*), pose a serious ecological threat if not controlled. Oil exploration occurs in the CREW. Residential development adjacent to CREW is increasing.

A SFWMD contract project assessing CREW hydrologic, hydrogeologic, and biological resources was recently completed (Gee and Jenson 1993). This study provides strategies for protecting CREW ecological and hydrological resources.

**Hydric Pine Flatwoods**

Slash pine forest acreage in Southwest Florida declined 88% from 1900-1989 (Mazzotti et al. 1992). Noss et al. (1995) list slash pine forests in Southwest Florida as one of the endangered ecosystems in the U.S. Large acreages of hydric pine flatwoods have been lost to logging, development, and agricultural activities (Beever and Dryden 1993). Habitat destruction from residential and commercial development and citrus conversion continues.
Melaleuca and other invasive exotic plants are a serious ecological problem. Anthropogenic activities alter natural surface and groundwater hydrology. Drainage of hydric pinelands greatly increases susceptibility to exotic plant invasion (Wade et al. 1980).

**Naples Bay Ecosystem**

The Naples Bay estuarine ecosystem includes Naples Bay, Gordon River, Rock Creek, Haldemen Creek, and Gordon Pass. Water quality in this system has degraded (Collier Co. 1993a). Water quality problems include high nutrient levels (especially ammonia), high chlorophyll $a$, low DO, and high fecal coliform bacteria. State water quality standards have been frequently violated, especially bacteria levels. Water quality problems are partially attributed to increased urbanization of the watershed.

**CURRENT SCIENCE ACTIVITIES**

Ongoing, planned, and proposed science projects, as related to issues identified in the previous section, are listed below by agency or organization.

**Alteration of Freshwater Inflow to Estuaries**

**Caloosahatchee Estuary**

**SFWMD**

Recently developed a research plan that addresses the Caloosahatchee estuary freshwater inflow problem (SFWMD 1993b). Objectives of the plan are to: 1) determine the optimal freshwater inflow range (quantity and timing) that provides the salinity gradient necessary for healthy biological communities; 2) develop "real-time" field monitoring and management capabilities; 3) establish estuarine water quality and nutrient loading limits; and 4) protect listed species. Ongoing or proposed science activities include:

- Evaluation of alternative Lake Okeechobee release schedules (includes developing ecological performance measures based on indicator species).
- Salinity modeling and monitoring.
- Biota assessments.
- Water quality and basin nutrient loading assessments.

If implemented as proposed, this program should provide the necessary scientific information to facilitate restoration of an appropriate freshwater flow pattern into the tidal Caloosahatchee. However, the indicator species approach outlined in the plan should be independently evaluated. The use of other ecosystem attributes, such as landscape features, to optimize salinity patterns should also be evaluated. SFWMD should immediately establish a comprehensive water quality monitoring program in the Caloosahatchee estuary, as exists in the St. Lucie estuary (Germain 1994).

**Charlotte Harbor System**

**SFWMD**

- Identification of optimal freshwater flows, for SFWMD portion only (SFWMD 1993).

**USGS**

- Salinity distribution and model related to freshwater inflow.
Faka Union Bay and Golden Gate Estates

SFWMD

> Development of a hydrologic restoration plan (SFWMD 1994) for southern Golden Gate Estates with the goals to: 1) restore wetland hydroperiod and surface water sheetflow; 2) restore more natural freshwater inflow pattern to estuaries; 3) improve groundwater recharge; 4) enhance surface water deliveries to Fakahatchee Strand; and 5) reduce overdrainage of Fakahatchee Strand and Florida Panther NWR lands.

Collier County

> Surface and groundwater quality monitoring in Golden Gate Estates and Faka Union Canal system (Collier County 1993b).

Charlotte Harbor Estuarine Ecosystem

SWFWMD (For SWFWMD portion only; see SWFWMD 1993 for description.)

> Water quality monitoring program.
> Development of resource-based water quality targets and pollutant load reduction goals.
> Habitat mapping and assessment.
> Toxics assessment
> Diagnostic watershed assessment: quantification of point and nonpoint source pollution.

SFWMD (For Caloosahatchee Estuary only; see SFWMD 1993 for description.)

> Water quality and basin nutrient loading assessments.
> Salinity modeling and monitoring.
> Biota assessments.

USGS

> Charlotte Harbor Environmental Assessment Program (see SWFWMD 1993 for description); only work left is completion of the following project reports:
  · Tidal flow, circulation, and flushing characteristics.
  · Salinity distribution and model related to freshwater inflow.
  · Physical, chemical, and biological characteristics under present and future environmental conditions.

FMRI (M. Mitchell, pers. comm.)

> Fisheries-independent monitoring program: provide long-term database on juvenile fish abundance and fisheries abundance trends.
> Assessment of seagrass damage by boat propeller scarring.
> Functional assessment of seagrass beds: includes assessment of fish and invertebrate assemblages.
> Long-term seagrass monitoring: detailed in situ monitoring of seagrass distribution, composition, abundance, and productivity.

FWS

> Migratory bird inventories (NWRs, ongoing)
Potential impacts of mosquito pesticide spraying on living resources and FWS lands (Ecological Services, proposed).

**Mote Marine Laboratory**

- Sublethal effects of mosquito pesticides on nontarget organisms.

**FGFWFC**

- Bird rookery inventories

**City of Cape Coral** (C. Jarvis, pers. comm.)

- Water quality monitoring of Cape Coral canal system.

**Lee County** (L. Riley, pers. comm.)

- Development of a surface water management plan that will include water quality monitoring.
- Seagrass and wetland habitat mapping and trend analysis (GIS-based).

**Freshwater Caloosahatchee River**

**SFWMD**

- Water quality monitoring at locks (see Germain 1994).
- Development of a basin assessment for the river upstream of Franklin Lock (contract with Camp, Dresser, and McKee). Phase One has been completed and includes literature review (CDM 1991a), documentation of point and nonpoint pollution sources (CDM 1991b), hydrologic model selection (CDM 1991c), monitoring program design (CDM 1992a), and QA/QC plan (CDM 1992b). The pollutant source documentation (CDM 1991c) is inadequate because CDM conducted only a one-day, qualitative field survey. Phase Two will entail water quality and quantity monitoring and data analysis. Phase Three will include entering collected data into the SFWMD GIS database, computer modeling, and developing management recommendations.

**Lee County** (J. Cassani, pers. comm.)

- Water quality, aquatic macrophyte, and benthic invertebrate monitoring or surveys by the Aquatic Plant Control Division.

**USGS**

- Water quality and other studies as part of the NAWQA Program (McPherson 1994).

**Estero Bay Estuary and Watershed**

**Lee County**

- Water quality monitoring in southern Estero Bay.
- Hydrologic study of Six Mile Cypress basin as part of Lee County Surface Water Master Plan.
- Water quality monitoring in Six Mile Cypress Slough Preserve.
- Effectiveness of various herbicide treatments to control exotic plants in Six Mile Cypress Slough Preserve.
**Citrus Development and Other Agricultural Issues**

**SFWMD**

- Contracted comprehensive environmental assessment of preserved and created wetlands within a citrus development in Caloosahatchee basin (Gator Slough). Data collection complete; report in preparation.

**FWS**

- Proposal to investigate environmental contaminant (nutrient, pesticide, metal) inputs and effects to Florida Panther NWR from agricultural runoff (D. Morrison and K. Edwards, unpublished proposal).

**IFAS**

- Proposal to assess water quality of agriculture runoff flowing into CREW, to determine effectiveness of wet detention areas to improve water quality of agriculture runoff, and to modify and verify a computer model for assessing hydrologic and water quality effects of citrus grove design and management practices (J. Capece, unpublished proposal).

**Corkscrew Regional Ecosystem Watershed**

**SFWMD**

- Contract study to ascertain CREW hydrologic, hydrogeologic, and ecological resources. Study included projects to evaluate impacts of adjacent wellfields, develop monitoring network and baseline data, inventory and map (GIS) plant communities and habitat types, integrate habitat types and their water needs, and develop strategies to protect CREW hydrological and ecological resources (CREW Trust 1992). Recently completed (Gee and Jenson 1993).

**IFAS**

- Proposal to assess water quality of agriculture runoff flowing into CREW, determine effectiveness of wet detention areas to improve water quality of agriculture runoff, and modify and verify a computer model for assessing hydrologic and water quality effects of citrus grove design and management practices (J. Capece, unpublished proposal).

**FGFWFC**

- Wildlife surveys, including population censuses of game and nongame species (CREW Trust 1992).

**Lee County**

- Development of surface water management program, which will include water quality monitoring.

**Naples Bay Ecosystem**

**Collier County**

- Limited water quality monitoring.
INFORMATION NEEDS

The goal, objectives (based on SSG 1993), and scientific information needs for ecosystem restoration in Subregion 10 are summarized in Figure 19. Information needs are listed in detail in the following discussion.

Alteration of Freshwater Inflow to Estuaries

- Freshwater flow pattern into the tidal Caloosahatchee.
  - The indicator species approach proposed by SFWMD should be independently evaluated.
  - Use of other ecosystem attributes, such as landscape features, to optimize salinity patterns should also be evaluated.

- Work is needed on spreader waterways to determine the best design to perform intended ecological and hydrological functions.

Charlotte Harbor Estuarine Ecosystem

- A comprehensive, integrated SWIM plan for the entire system. Major science projects should also be system-wide. Two water management districts share jurisdiction for the Charlotte Harbor system, like Indian River Lagoon; however, unlike Indian River, there is no joint system-wide SWIM plan. SWFWMD has a SWIM plan for its portion, but SFWMD does not for its portion. Likewise, most SWFWMD science projects cover only SWFWMD jurisdiction. Note: The Charlotte Harbor system and Estero Bay have been nominated for National Estuary designation; NEP status could facilitate coordinated scientific, management, and restoration efforts.

- GIS-based habitat and land-use trend analyses for the entire system every 3-4 years.

- A water quality monitoring program for the SFWMD portion, including the tidal Caloosahatchee, to complement SWFWMD portion.

- A system-wide nutrient and other pollutant loading study (including septic tanks).

- System-wide hydrologic and circulation model (current USGS study may meet this need).

- Diagnostic watershed assessment for SFWMD part to complement that being done in SWFWMD portion.

- Nutrient limitation and dosing experiments on seagrass-seagrass epiphyte-fleshy macroalgae-phytoplankton complex, ideally in several areas of estuary.

- Irradiance limitation and sedimentation experiments on seagrass; closely coupled with nutrient limitation study.

- Predictive model of benthic vegetation change related to water quality and pollutant loading.

- Freshwater inflow studies: see previous section.

- Field and laboratory studies of chronic and sublethal effects of mosquito pesticides to nontarget species (various life stages), especially repeated applications and extended exposure.

- Mosquito adulticide drift studies and ecological effects.

- Continued efforts on alternative (nonpesticide) mosquito control methods.
Protect and restore the natural ecosystems of Southwest Florida in the face of rapid population growth and urban and agricultural expansion.

Improve or maintain water quality. Eliminate or minimize habitat loss and degradation and restore degraded habitats. Maintain or restore more natural hydrology, including freshwater inflow to estuaries.


Assess nutrient and contaminant loading assessments. Water quality monitoring and trend analyses. For seagrass community, nutrient threshold experiments, light limitation and sedimentation experiments, and predictive models of response to water quality changes. Effects of mosquito control pesticides. Effects of agriculture pollutants.

BMPs to reduce agricultural pollutants. BMPs to reduce urban pollutants. Pollutant reduction goals. Non-pesticide mosquito control methods. GIS-based habitat and land-use trend analyses, recognizing hydric pine flatwoods as distinct habitat type. Floral and faunal inventory and trend analyses. Ecosystem function assessment and trend analyses. Role of fire, storms, and biological disturbance on restoration actions. Ecosystem function assessment and trend analyses.


Figure 19. Goal, objectives, and information needs for...
**Freshwater Caloosahatchee River**

- Basin-wide nutrient and other pollutant loading study.
- Basin-wide GIS-based habitat trend analysis every 3-4 years.
- Assessment of biological resources in river.

**Estero Bay Estuary and Watershed**

There is little information on the ecology and hydrology of Estero Bay. The following studies are recommended:

- Assessment of biological resources in the bay, especially seagrass beds.
- Basin-wide nutrient and other pollutant loading study.
- System-wide water quality monitoring.
- Bay circulation and flushing model.
- Watershed hydrologic study, particularly addressing altered freshwater flow into Estero Bay.
- Nutrient limitation and dosing experiments on seagrass-seagrass epiphyte-fleshy macroalgae-phytoplankton complex.
- Irradiance limitation and sedimentation experiments on seagrass, closely coupled with nutrient limitation study.
- Predictive model of benthic vegetation change related to water quality and pollutant loading.

**Citrus Development and Other Agricultural Issues**

- Development and evaluation of techniques to improve irrigation efficiency and water conservation (surface and groundwater). Agriculture so dominates water use in the interior that even small improvements in efficiency would result in considerable water conservation (SFWMD 1992).
- Development and evaluation of BMPs to minimize pollutants in agricultural runoff.
- Potential ecological effects of agriculture on surface and groundwater quality; ecological effects of surface water runoff from agricultural lands.
- Potential ecological and hydrological effects of lowered water table, particularly in wetlands, from agricultural activities.
- More information on potential effects of environmental contaminants (pesticides, nutrients, metals) on wildlife in citrus groves.
- Development of a system for evaluating ecological and hydrological functions that can be used to better assess predevelopment environmental conditions and success of mitigation.

**Corkscrew Regional Ecosystem Watershed**

- System-wide habitat trend analysis every 3-4 years (GIS-based).
System-wide surface and groundwater quality assessment (GIS-based) (Gee and Jenson 1993).

Ecological and hydrological effects of agriculture adjacent to CREW, especially potential nutrient and other contaminant loading from agriculture runoff.

Examine possible hydrological and ecological impacts of oil exploration.

Ecological and hydrological effects of residential development adjacent to CREW.

Ecological and hydrological effects of municipal wellfields adjacent to CREW.

Flint Pen Strand subbasin hydrologic and hydraulic study to assess the impact of new and proposed controlling structures in Kehl canal system (Gee and Jenson 1993).

**Hydric Pine Flatwoods**

The following recommended science needs are from Beever and Dryden (1993).

Recognition of hydric pine flatwoods as a separate biological community type. Landscape-scale inventory and monitoring, including historical distribution and aerial coverage, temporal changes.

Floral and faunal inventory and monitoring, including protected species. Examination of wildlife habitat value of hydric pine flatwoods.

Ecological and hydrological effects of invasive exotics.

Hydrologic studies including surface water hydrologic conditions needed to maintain system and groundwater recharge potential.

Influence of fire regimes in maintaining natural plant species composition and diversity.

**Naples Bay Ecosystem**

Assessment of biological resources in the bay.

Basin-wide nutrient and other pollutant loading study.

System-wide water quality monitoring.

**Endangered and Threatened Species**

Science supporting protection and recovery of endangered and threatened species should receive higher priority in Subregion 10 relative to other subregions because this subregion has the greatest rate of urban and agricultural growth. Rapid assessment approaches may be needed.

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