PROGRESS IN WETLAND MANAGEMENT IN ST. LUCIE COUNTY, FLORIDA BY THE ST. LUCIE COUNTY MOSQUITO CONTROL DISTRICT

HISTORY

St. Lucie County is in east-central Florida along the Atlantic Ocean. Its eastern side is a 20-mile-long barrier island, Hutchinson Island. The island's western shore borders on the Indian River Lagoon (IRL), an estuary with less than 3 feet of tidal range and more than 5000 acres of wetlands. The wetlands mostly are flat or gently sloping and rarely were flooded by lunar tides, historically. High "wind-tides" from northeasterly and easterly winds during 4-6 weeks a year (late September to October) typically were the only cause of sustained flooding. Lunar high tide inundation (lower than the wind-tides) was restricted by piles of storm-tossed shells and plant debris at the mean high water line (called a wave-action levee). In IRL high salt marshes, this levee was formed at the extreme water-ward limit of the marsh. Because of the low flooding frequency, vegetation was dominated by black mangroves, white mangroves, saltworts, and glassworts, all of which can withstand high salt marsh conditions.

Before dike construction, direct and indirect export and import of biomass took place between the estuary and marshes through biological, chemical, and physical means. Direct tidal and rainwater export of plant and attached bacterial matter occurred by surface runoff and groundwater transport. Fiddler crabs reworked and oxidized sediments along the margins of the marsh and were food for marine predators (indirect export) along the perimeter. Wading birds, shorebirds, waterfowl, and transient marine organisms imported and exported organic materials by feeding in the marsh. The marshes were seasonally used as nursery grounds by migratory fish like snook and tarpon, and as breeding and nursery grounds by resident fish (e.g., sheepshead minnow, mosquitofish, sailfin molly) during flooded periods and in low areas that retained water.

Nuisance Insects

The 1865 survey maps officially showed St. Lucie County as part of "Mosquito County." Historical reports described people burying themselves in the sand if on land, and wrapping themselves in a sail if in a boat, to avoid mosquitoes. Many long-time residents still recall the smudge pots that made it possible for them to sit outdoors on the porch during the evening. Cattle and horses sometimes were suffocated by enormous broods of salt marsh and fresh-floodwater mosquitoes.

Salt marsh mosquitoes lay eggs (as many as 200/batch) in depressions in muddy sediments or in leaf-litter, after heavy rainfalls or wind-tides have flooded the marsh. Repeated egglaying can occur during long periods of sediment exposure. Egg densities were found to average as much as 2383/square foot in the substrate, and larval densities of 170-870/square foot/year were found in the water (7.4-37.9 million larvae/acre/year). The thousands of acres along the Lagoon produced billions of mosquitoes per year, and many migrated as far as 20 miles to areas inhabited by humans.

First Attempts at Mosquito Control

During 1927-1935, St. Lucie County built 285 miles of ditches to control mosquitoes by draining breeding areas and keeping the ground too dry for normal egg hatching. That program was partly successful, but short-lived, because ditch maintenance was impossible to continue

during World War II. Wave-action levees actually made some ditches into better mosquito breeding habitat by limiting drainage.

Salt marsh sandflies continued to be a significant nuisance immediately after the ditching, and ditching might have made that problem worse, too. Up to 616,200 sandflies could be produced from a 2-foot wide, 1 mile long, ditch bank. The 285 miles of marsh ditches could have produced 70 million sandflies per day, and as many as 25 billion sandflies per year. In 1935, an experimental diking program was tested on sandflies. The initial work attempted to take water from the marsh, but it could not be removed fast enough with available pumps. Then, flooding the marsh was tried and found to be effective for controlling 99% of both sandflies and salt marsh mosquitoes by blocking them from laying eggs in the flooded areas.

Second Attempts at Mosquito Control

Although that study was successful, and one impoundment was partially maintained in operation until after WWII, DDT spraying became the preferred method of mosquito control in the 1940s and 1950s. DDT provided effective and economical control and was good as both an adulticide and a larvicide. By the late 1940s, salt marsh mosquitoes began to develop resistance to DDT, possibly from repeated use and/or its dual use for larvae and adults. Some strains (family groups) of mosquitoes have genes that can partly protect them from certain types of insecticide. That resistance helps them out-compete mosquitoes that do not have the resistance gene(s), when both are exposed to the insecticide. Dual use of insecticides (against both larvae and adults) can more easily increase this selection pressure because it eliminates non-resistant mosquitoes faster, allowing mainly resistant mosquitoes to survive. Resistance and harmful environmental effects ended the use of DDT. Then, other compounds were sought (BHC, Dieldrin), but they also quickly became unusable, for similar reasons or because of high cost.

Third Attempts at Mosquito Control

Further studies on diking, impounding, and flooding salt marshes were conducted in Brevard County during the mid-1950s. Following the success of those studies (99% control of mosquitoes and sandflies), the Florida Department of Health and Rehabilitative Services fostered a program of impoundment construction for mosquito control along the IRL. During 1958-1966, more than 41,000 acres of salt marsh were impounded along the east-central coast of Florida, including about 6000 acres in Saint Lucie County. Dikes were 30-50 feet wide and 2.5-5 feet high. The borrow-material to construct them was removed from the marsh and placed along the perimeter of the wetland. This created a perimeter ditch system, 3-6 feet deep and 25-50 feet wide. The natural red mangrove marsh fringe outside the dikes was left as it was, for protection from wave erosion.

The impoundment program was partly successful at reducing nuisance insects, improving the quality of life for residents, and allowing expansion of human development. However, it was environmentally costly. Long-term flooding with stagnant water and trapping of rainfall resulted in excessively high water level, low salinity (salt content), and periodic “marsh acidification” (from lack of salt buffering against hydrogen sulfide and sulfuric acid). High water destroyed much of the high marsh vegetation. It later was learned that long-term complete submergence of black mangrove pneumatophores (breathing structures) and low-profile salt-tolerant plants, like saltwort and glasswort, reduced their survival. After destruction of the original vegetation, red mangroves became dominant in more than half of the impounded marshes. Establishment of red mangroves was followed by a two- to four-fold increase in soil accumulation rates. This caused

increased elevation of the marsh floor, reduced water exchange further, and converted diked impoundments into carbon sinks (traps), leading to negative effects on estuarine productivity.

Balancing Mosquito Control with Habitat and Wildlife Protection

Isolation from the estuary caused loss of most of the natural estuarine-related functions of the salt marshes. There was reduced or no access for transient juvenile fish that were seeking nursery areas. Diversity of fish declined after impounding (in one case, from 16 species to five) during the 4-6 week natural flooding period in the fall, when transient species normally would use the marsh. In one impoundment connected to the estuary by one 30-inch-diameter culvert, 38 fish species used the perimeter ditches, compared with 12 species in an impoundment with no culverts. The culvert-connected ditches appeared to function like tidal-creeks, which suggested that culverts through the dikes, combined with seasonal opening of tide-gates, could re-introduce the nursery function to the marsh and result in other tidal-creek-like benefits.

It also was found that the marsh floor of an unmanaged open marsh is favorable for plant re-colonization, and the vegetation in high salt marshes is capable of surviving artificial flooding in the summer, if pneumatophores and low-profile plants are not completely submerged. This information supported the idea of promoting restoration and health of marsh vegetation by seasonal management employing strict water level control. Thus, the potential for restoring fish nursery usage and natural plant assemblages led to the Rotational Impoundment Management (RIM) protocol being adopted by the Subcommittee on Managed Marshes (SOMM).

Development of Current Methods

Large peaks in larval and juvenile fish recruitment to the salt marshes normally occur during March-April (striped mullet, etc.) and late August-September (snook, etc.). Because breeding of salt marsh mosquitoes and sandflies mainly happens during April-October, the SLCMCD adopted the RIM seasonal water-level management strategy. The marshes usually are closed in May before mosquito emergence can increase, then opened at the end of August to optimize estuarine and nursery functions. The open period of about 8 months ends for each marsh the following spring when mosquito breeding or infestation is found in or adjacent to it. Thus, each marsh usually is managed independently from the others, to have the shortest possible closure time.

Current Best Management Practices (BMPs) are based on improved Block Rotational Impoundment Management, modified open marsh water management, draw-downs, and wetland restoration. Optimal ratios for acres per culvert (10-16 acres/culvert), culvert per linear foot of perimeter ditch (1 culvert/500-900 linear feet), and acres per 7,000-gallon-per-minute pump (80-100 acres/pump) have been developed. SLCMCD impoundment strategies include artificial flooding in association with: vinyl sheet-pile discharge weirs and breaching (openings); season-long open culverts; season-long partly open culverts; and/or rotary ditching. Regional or Block Management focuses on individual species (or species groups) that have specific requirements, to fulfill those needs. One example is waterfowl enhancement in 20,000 acres of the Merritt Island National Wildlife Refuge. In St. Lucie County, Block Management provides mosquito and sandfly control, improved fish access and utilization, better foraging opportunities for wading birds, and general improvement in native plant and animal populations, while controlling exotic plants and pest mosquitoes with minimal pesticides.

RESULTS

These strategies can be employed over a wide range of impoundments. Since 1994 in St. Lucie County, 4467 acres of coastal wetlands and adjacent natural uplands (including more than 54% of the barrier island) have been placed under county management, through land acquisition, cooperative management with state and private landowners, and private donations (for mitigation, etc.).

Current restoration totals are: 3501 acres reconnected (and now under active management); 820 acres reconnected (not yet under active management); 344 perimeter culverts installed; 19 culverts under Highway A1A installed and/or operated; 24 water pump and aeration stations; and 54 water pumps with more than 66.5 billion gallons per year capacity. Management objectives include: restoration of natural hydrological functions through tidal range duplication; water quality improvement to sustain a broad range of estuarine biodiversity resulting from specialized tide-gate, aeration, and pumping operations; control of invasive exotic plants and restoration of natural vegetation; draw-down for wading bird foraging enhancement; block or regional impoundment management for multiple-species use of the impoundments; management-season fish recruitment via open tide-gates; and construction of public access infrastructure.

Recent and current work includes: hydrological modeling; water quality monitoring; nutrient loading; sediment chemistry; copper distribution; seagrass monitoring; snook and tarpon tag, release, and track programs; shrimp life history; status of zooplankton, phytoplankton, wading birds, other wildlife; benthic ecology and restoration; mangrove ecology and restoration; tidal creek restoration; shoreline colonization and recruitment; fish attractant device (FAD, reef ball) recruitment and monitoring; spotted seatrout spawning success relative to coastal wetland restoration; relationships between spotted seatrout spawning and non-point source discharge; causes of estuarine harmful algal blooms (HABs).

Impact on Mosquitoes

Previously, mosquito eggs had accumulated from nearly constant spring, summer, and fall egglaying, and large broods of mosquitoes and sandflies were produced after the flooding caused by summer rains or fall wind-tides. The longer the egglaying period, the more aerial and ground pesticide applications were required. Aerial adulticiding was performed several times per year. Ground adulticiding was conducted several hundred times per year on the barrier island. Aerial larviciding of the salt marshes occurred over as many as 30,000 acres in the natural marshes and unmanaged wetlands.

Seasonal water-level management was found to significantly reduce the need for pesticides, which often could be completely eliminated. When an impoundment has been managed during the year, salt marsh mosquitoes generally will not produce large broods in the fall. This "control carryover effect" is achieved because summer management arrests summer egglaying. Wind-tides following the management period flood the marshes often enough to prevent recurrence of egglaying. This result is achieved only if enough culverts are in the marsh to mimic estuarine tidal heights. More than four tidal floods per month at 1- to 2-week intervals lead to reduced egglaying. Pesticide use is greatly reduced and nutrient export is greatly increased with multiple culverts.

Aquatic Animals

Spacing of 800 feet or less between culverts is near optimal for fish recruitment, leading to improved water quality and more scattered fish distribution than with culverts farther apart.

Seventy fish species were found in a 188-acre marsh connected to the estuary by seven culverts. Many of those species have strict dissolved oxygen, salinity, or other water quality requirements that must be met for them to inhabit an area. Adequate culvert numbers and spacing will supply those requirements for a greater range of species. Migrating fish that were studied became somewhat blocked by tide-gates that opened only under tidal pressure. Therefore, tide-gates now are tied open and/or completely removed from culverts during the open impoundment period.

Stagnant conditions in saline water can cause build-up of hydrogen sulfide, a byproduct of anaerobic microorganisms (they do not need oxygen). Sulfuric acid can build up following rainfall, driving pH to as low as 4.0 (acidic). Hydrogen sulfide is very toxic to fish and other animals, and sulfuric acid can be destructive to marsh vegetation and animals. The modified tide-gate weir's ability to discharge surface rainwater helps to moderate pH by keeping salinity high. Hydrogen sulfide is flushed out through open or partly open culverts during the closed period by constant pumping (one 7000-gpm pump per 70 acres). This also exports nutrients and increases concentration of dissolved oxygen by reducing the chemical oxygen demand (COD) imposed by hydrogen sulfide.

In 2001, a method was developed to allow a simple flap-gate to be opened halfway at the bottom of the culvert. The following year, all managed impoundments had an open or partly open culvert(s), with such a “flip-gate” to restrict flow during low tides when water loss exceeded that supplied by pumping. With 30 acre-feet of capacity per 7000-gpm pump per day, the typical culvert discharge of 50 acre-feet can be balanced by multiple pumps, thus increasing the outflow of nutrient-laden water from the marsh, while allowing animals in and out. Water quality is enhanced because stagnant fresh water cannot accumulate in the impoundment, and water turnover rate is lowered from the previous 7-10 days to 3-3.5 days. Snook and tarpon use the open culverts to go in and out during the management season, with recruitment (12-24 inch tarpon seen in July and August) occurring in as little as a few days after culvert opening. The flip-gate allows easy manipulation of the lower part of the culvert, passage of fish, and more consistent water management, while continuously conveying marsh productivity to the estuary.

Aeration and Dissolved Oxygen

When pumps suffer mechanical failure, fish usually seek oxygen by swimming against the water flow, which brings them into confined areas at pump stations and adjacent ditches, where water levels are highest and water continues to flow outward for a while even with the pump(s) off. Accumulation of many fish (tens of thousands up to several million), results in over-consumption and depletion of dissolved oxygen (D.O.). Two unusual species that can tolerate low oxygen are the Atlantic tarpon and common snook. Tarpon can stand D.O. near zero, because they can directly breathe air. Young snook can survive D.O. near 1 part per million for a short time (if hydrogen sulfide is not present), but 3 ppm or more is best. Many other fish, like seatrout and mullet, need a constant minimum D.O. of about 4-5 ppm. Therefore, as a backup to the water pumps, 3-horsepower electric aerators have been installed at pump stations to provide constant aeration. These are especially helpful during periods of heavy cloudiness, when oxygen is used by algae instead of produced like it is in sunlight. In one case, during heavy prolonged overcast, D.O. remained at 6.2 parts per million in an aerated impoundment, while D.O. in the estuary dropped to 2.9 ppm. There has been no fish mortality at pump stations equipped with aerators since the aerators were installed.

SLCMCD has documented improved water quality resulting from more culverts, during 1984 to the present. D.O. increased from an average of 2.4 ppm with an 80.7 acre/culvert ratio in 1984, to 5.8 ppm with a 26.1 acre/culvert ratio in 1991. As more culverts were installed and

pumping was increased to one 7000-gpm pump per 80-100 acres, operated 24 hours a day, high D.O. has been even more consistent. Fish stress events dramatically declined in both occurrence and number of fish affected.

Vegetation

The impounded wetlands now are mostly a mixture of high salt marsh and mangrove swamp. Close to half are nearly pure red mangrove swamps (about 90% coverage). The rest are about 60% covered with original salt marsh vegetation (black and white mangroves, saltwort, glasswort.). Attempts are on-going to restore high salt marsh vegetation in the remaining un-vegetated areas (40% of the 2000 acres dominated by high marsh plants). SLCMCD successfully maintained water levels below normal control height in impoundment 16A (Jack Island Preserve State Park) and reduced or completely eliminated artificial flooding in impoundment 24 (Avalon State Park Addition) long enough to achieve plant regeneration. Modified tide-gate weirs (overflow tide-gates) also automatically discharge excess fresh water, to prevent overflooding of the natural high marsh plants and to maintain appropriate salinity and pH.

Above-ground primary production of pure red mangrove forests in a managed impoundment, an unmanaged impoundment, and a fringe forest was 4335, 4016, and 5384 grams/square meter/year. Although seasonal flooding temporarily reduces litterfall and biomass accumulation, the annual total was greater for the managed swamp than for the unmanaged swamp. The success of red mangroves in managed impoundments might result from the "energy subsidy" provided by end-of-season draw-downs, which release nutrients by oxidation of exposed sediments. An unexpected benefit of seasonal artificial flooding was prevention of invasion by exotic species like Brazilian pepper and Australian pine (both common at disturbed sites in Florida).

Birds

Draw-downs have been used by the District to enhance wading bird foraging success through mid-season lowering of water levels within selected impoundments, by discharging more water than is pumped in. This concentrates water and marsh resident fish (minnows, etc.), making them easily accessible for wading birds, including migratory ones. Young birds especially benefit because their feeding skills have not developed fully.

Control of Mosquito-borne Diseases

Several mosquito species that are potential vectors of human viruses like West Nile virus and St. Louis encephalitis occur in St. Lucie County. Other possible world-wide, emerging or re-emerging diseases include: microfilarial diseases, malaria, dengue fever, and yellow fever. Control of vector mosquitoes lessens the health risk to humans and animals. Under current management, no human occurrences of these diseases have been reported.

Public Usage

Once mosquito impoundments are restored and management is initiated, public access amenities are installed to enhance recreational use. These include: roads, parking areas, trails, fishing /observation piers and docks, crabbing docks, birdwatching platforms, and educational covered/elevated observation areas. SLCMCD supports educational boat and walking tours for children and adults led by an Audubon Warden. More than 31,000 people have participated so

far. Most had never before been on the estuary in a boat, and were unaware of the natural areas available for recreation. This outreach effort has been very successful in helping to raise awareness of coastal wetland ecology and mosquito control management practices in Saint Lucie County.

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