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Source Reduction [1]

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Throughout Florida, there are many sites capable of producing large numbers of mosquitoes that must be controlled for the health and well-being of both residents and tourists. Some examples of these mosquito-producing sites include marshy coastlines, freshwater permanent lakes and ponds, low-lying pastures, freshwater marshes and man-made containers. Ideally, the best method of controlling mosquitoes is to eliminate mosquito-producing sites altogether. This is called source reduction.

Source reduction, also referred to as permanent control, physical control or water management, virtually eliminates the need to larvicide (use chemicals to kill larva) and greatly decreases the need to adulticide (use chemicals to kill adult mosquitoes). Source reduction is an important part of a complete pest management program. Unfortunately, it is often underused.

Mosquito-producing Habitats

There are several major categories of mosquito-producing sites that should be considered for permanent control measures.

Freshwater lakes, ponds and retention areas. Although it is possible to fill small ponds that produce mosquitoes, this is not feasible for large, permanent bodies of water or for areas set aside for retaining stormwater or wastewater. In these situations, other effective options include minimizing emergent vegetation (plants with roots in the bottom of the pond and tops that protrude from the surface, e.g., cattails) and maintaining steep banks. *Culex* and *Anopheles* mosquitoes are frequently produced in these habitats.

Freshwater swamps and marshes. Large inland permanent marshes can produce several different mosquito species: *Culex, Culiseta, Psorophora, Mansonia, Coquillettidia* and *Anopheles* . Source reduction is difficult in these areas because

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environmental laws greatly restrict what can be done to alter these environments. These changes are referred to as habitat manipulations.

Temporarily flooded lands. Pastures and agricultural lands frequently generate huge numbers, or broods, of *Aedes, Psorophora* and *Culex* mosquitoes. An effective method of source reduction in these habitats is improved drainage by filling regrading or ditching.

Containers. Containers such as flower pots, cans and tires are excellent habitats for several *Aedes* and *Culex* species. The container-breeding mosquito problem can be solved by properly disposing these containers or ensuring they do not collect water.

Salt marshes. In Florida's not-so-distant past, extensive coastal salt marshes (flat land subject to flooding by salt water) produced enormous *Aedes* broods. This made coastal human habitation virtually impossible. Because of these problems, salt marshes have received considerable attention by mosquito control programs, often in the form of source reduction projects. To understand source reduction in salt marshes, it is important to know the different types of marshes.

In Florida, daily tidal changes are small when compared with seasonal variations in tides. In other words, wind-generated water movements can be more important than lunar tides. The difference between low marshes and high marshes is that low marshes are flooded by daily tides and high marshes are flooded by large seasonal tides, strong wind tides or rainfall.

In most locations, these tidal conditions produce more high marshes than low marshes. High marshes produce saltmarsh mosquitoes and, therefore, require physical control measures. Florida's salt marshes, which are inhabited by salt-tolerant vegetation, are broadly classified by Provost (1967) into three main vegetative types:

- **Grass marshes** are typically low marsh dominated by cordgrass (*Spartina alterniflora*) or black rush (*Juncus roemerianus*). Grass marshes in high marsh are usually vegetated by salt grass (*Distichlis spicata*) or salt marsh grass (*Spartina patens*) and can be prolific producers of *Aedes sollicitans* , the eastern saltmarsh mosquito. In the Florida Panhandle, grass marshes dominate.
- **Scrub marsh** is typically high marsh dominated by saltwort (*Batis maritima*) and glasswort (*Salicornia* spp.), but also includes mangrove. Scrub marsh dominates on the east coast from roughly St. Augustine to Palm Beach, and on the west coast from Tampa Bay to Naples.
- When high- or low-marsh areas are dominated by mangrove trees, they are called **mangrove swamps** . In low-marsh locations, red mangrove (*Rhizophora mangle*) dominates while in high-marsh locations, black mangrove (*Avicennia germinans*) dominates. Red mangroves, with their extensive prop-roots, protect the shoreline against erosion. Generally a berm forms behind this row of mangroves and restricts water movement between the marsh and estuary. Low-marsh and high-marsh vegetation differs from region to region. From Naples and Palm Beach southward, mangrove swamps dominate. Mangrove swamps in high-marsh locations most commonly produce *Aedes taeniorhynchus* . The approximate northern limits of mangroves are shown in Figure 1 .

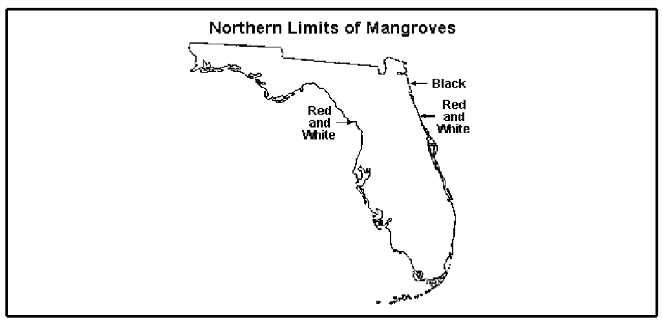

Figure 1 .

Uplands Adjacent to High Marshes

Adjacent to high marshes are hardwood forests, or hammocks, consisting of oaks, palms and, in the low-lying areas, many tropical and subtropical plants. Palmettoes, Spanish bayonets, Cherokee beans, cocoplums, seagrapes and other plants dominate the drier, sandy high hammock areas that rarely produce mosquitoes. Along the area between the hammock and the high marsh is usually a fringe of white mangrove (*Laguncularia racemosa*) and buttonwood (*Conocarpus erectus*).

Source Reduction for Saltmarsh Mosquito Control

Historical Methods

Several different source control efforts have greatly reduced, but not eliminated, saltmarsh mosquito production in these marshes.

Deep ditching. Beginning in the late 1920s, high marshes were ditched by hand, with explosives or with heavy equipment, particularly draglines, to dewater the marsh within several days of flooding. This prevented sufficient time for adult mosquitoes to emerge and allowed larvae-eating fish access to larvae. This technique was largely unsuccessful: ditches were not always dug where they were needed most, many soon were obstructed, especially in the area between the ditch and the estuary, and fish were generally not present in sufficient numbers to provide appreciable control. Furthermore, the ditch banks made perfect breeding sites for biting sandflies (*Culicoides*), and this made the biting-insect problem even worse.

Filling. In the past, mosquito-producing areas were sometimes filled as a method of source reduction. Because it was too slow and expensive, it was abandoned along Florida's east coast in the 1950s. Current environmental laws all but prevent wetland filling because it eliminates valuable wetland habitat. In some instances, filling has produced good sandfly breeding habitats. Fissures, or openings, that develop in the fill can also produce floodwater mosquitoes.

Impounding. Mosquito control impoundments are high salt marshes that are surrounded by earthen dikes. Impoundments are generally flooded for mosquito control from May to October with water pumped from the estuary. Impounding and flooding eliminate oviposition sites for saltmarsh mosquitoes and have been shown to be both effective and economical in reducing their populations. However, some environmental problems have resulted from isolating and flooding these wetlands and have received considerable attention over the past decade. Years ago in a few locations, water was pumped out of impoundments as a source-reduction technique. It was unsuccessful because it was impossible to completely dewater the area before mosquitoes were produced.

Modern Methods

Environmental considerations. Before the 1970s, when the majority of the ditching, filling and impounding construction was completed, only mosquito control was considered. Little concern was given to environmental issues. Today, when source reduction projects are designed, close attention must be given to minimizing negative effects on the salt marshes. In 1986, the Subcommittee on Managed Marshes (SOMM) was formed (Florida Statutes Chapter 388.46), highlighting the importance of mosquito control as well as environmental issues.

SOMM, a subcommittee of the Florida Coordinating Council on Mosquito Control, has developed guidelines for impoundment and mosquito-control ditching management plans. These guidelines state that management plans should incorporate the mutual objectives of mosquito control, fish and wildlife resources and water-quality enhancement. The most desirable environmental benefits appear to be those that attempt to recreate natural marsh functions while controlling mosquitoes. Reducing insecticide use is also an important goal.

Management plan development. When developing the best management plan for a marsh, one must carefully consider the impoundment's biological, topographical and hydrological characteristics. The following are considered to be important management objectives:

- effective mosquito control minimizing the use of insecticides;
- optimal interchange of nutrients and organisms between the marsh and lagoon;
- effective water circulation within the marsh;
- water level controls that will enhance desirable marsh vegetation; and
- protection or enhancement of water quality both within and out side the marsh.

The following is a list of information required to develop a plan that achieves the above-listed goals.

- **Breeding history.** Historical and current larval mosquito and (if available) sandfly production data.

- **Topography.** Topographical survey of representative marsh locations.

- **Vegetation.** A survey of major vegetation species.

- **Water quality.** Representative water-quality measurements (dissolved oxygen and salinity, or salt content).

- **Water-control structures.** Determination of best location and number of water-control structures (e.g., pump stations, culverts, ditch sills). Determination should consider acreage, marsh surface elevations and tidal exchange data (representative data are available at the St. Lucie County Mosquito Control District for 30 inch diameter culvert exchanges under various scenarios).

- **Management schedule.** For impoundments, the culvert opening and closing schedule attempts to minimize the closed period. Closure times are based on historical mosquito and sandfly production patterns, rainfall and expected tidal inundations. Flooding elevation should be minimized to protect vegetation while preventing the vast majority of mosquito production.

Rotary ditching

Ditching can be used in both salt marsh or freshwater locations to improve water management generally by enhancing drainage, which eliminates mosquito-producing sites. Candidates for rotary ditching include marshes, dredge spoils, temporary grassy ponds and savannas when vegetated with grasses and small scrubs if they are not rocky.

Ditch cleaning or new construction is possible in areas of woody vegetation if planned carefully. Experience has shown that poorly engineered ditches can produce more mosquitoes than the area did before construction.

In Florida the construction of shallow ditches, using high-speed rotary equipment that scatters spoil evenly over the marsh surface, is used in two management techniques:

1. in impounded marshes connected to the estuary by breaches or culverts; and,

2. in unimpounded marshes using Open Marsh Water Management (OMWM) techniques. A ditching network frequently connects shallow ditches to permanent water bodies (ponds or canals). Where it is impossible or impractical to connect to major waterways, it is possible to dig a pond deep enough to hold water throughout the year. Radial ditches are then connected to mosquito-producing locations. The pond should be stocked with larvae-eating fish that can provide some control when rainfall allows these fish access to mosquito-breeding sites.

Over the past 15 years OMWM, using ponds, rotary ditches and ditch sills, has been implemented in many coastal locations throughout the United States (see references). Research in Florida on the total ecosystem effects of rotary ditching are incomplete. However, management experience indicates that rotary ditching can reduce the need for larviciding, while increasing the hydrological connection between a marsh and estuary.

Rotary ditching is generally considered more environmentally acceptable than deep ditching because spoil material from these shallow ditches is evenly distributed over the marsh surface. This eliminates the problem of the marsh accumulating spoil material and the resulting invasion of exotic vegetation. As with any environmental manipulation, there are advantages and disadvantages to rotary ditching. A study is currently under way in Charlotte County to determine ecosystem effects of this source-reduction technique. (For the latest results, contact Robert Ward, Charlotte County MCD.)

Advantages of Rotary Ditching

Time-tested equipment. Rotary ditchers are connected to suitable tractor/carriers. They have been used for years in agriculture and therefore are time-tested. The tractors are usually modifications of existing equipment. The equipment can be mounted on carriers that have lighter ground-bearing pressures than standard heavy excavation equipment. When mounted on amphibious carriers, the total package can be much smaller and less encumbered.

Efficiency. Rotary ditchers are more efficient than conventional methods; they cut, clean and shape in one continuous action and therefore can handle all types of soil and small roots. Trapezoidal-shaped ditches 2 feet deep and 3 feet wide at the top, can be cut at speeds up to 5,000 feet per hour (Figure 2). Rotary ditchers work well but are slower in hard-packed dry clay and when small stones are present. With a narrow tractor width, rotary ditchers can operate in wooded habitats and maneuver around trees.

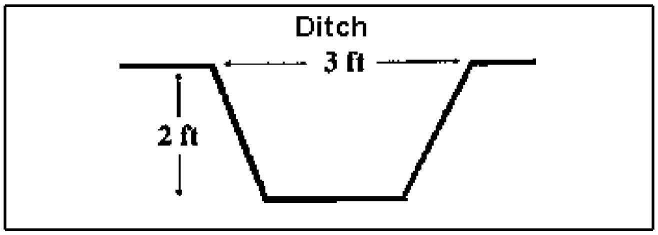

Figure 2 .

Broad spoil dispersal. Excavated spoil is finely scattered over a broad, continuous area adjacent to the ditch, resulting in spoil less than 3 inches deep. This even distribution avoids the problems associated with spoil pile and ditch berms created with conventional excavators. That is, rotary ditching does not create raised areas that have two negative affects: eliminating marsh habitat and providing habitat for undesirable vegetation, such as Brazilian pepper (*Schinur terebinthifolius*) and punk trees (*Melaleuca quinquenervia*). The raised areas may also affect drainage patterns.

Vegetation impact. Impact to vegetation is usually limited to the ditch itself, as the tractor will climb over most vegetation, allowing it to spring back, causing little damage. Marsh ditching seems to affect vegetation as only a top-dressing of soil might affect a lawn.

Because rotary ditchers distribute material evenly and do not form spoil piles, they should receive serious consideration for any mosquito-control ditch construction. Environmental regulatory agencies generally look favorably on rotary ditching of impoundments if it allows keeping an impoundment open permanently for a greater portion of the year.

Disadvantages of Rotary Ditching

Indiscriminate spoil placement. Rotary ditchers can throw debris up to several hundred feet from the edge of the created ditch, depending on soil characteristics. Therefore, care is necessary when working in congested areas. Deflectors, which can help control the dispersal of excavated spoil, are standard on all machines.

Ditch stability. In loose soils, the size and shape of the finished ditch cannot be maintained due to erosion. The width of the ditch is fixed by the depth. Therefore, a shallow ditch must also be narrow.

Pond construction limitations. Rotary equipment can construct small ponds, but is limited as to depth and shape. It generally cannot dig below 4 feet on a single pass.

Gearing considerations. The tractor/carrier requires a hydrostatic drive that matches ground speed to the cutter while still supplying maximum power to the ditcher. Hydrostatic systems are expensive. Although very low-geared tractors can be used, they will never be as efficient as hydrostatically equipped units. In data sheets, rotary ditcher manufacturers are typically conservative regarding their equipment's true horsepower requirements. Because the unit will generally be operated at maximum speed, an overrated power unit should be specified.

Waterproofing equipment. Unlike most excavation equipment, rotary ditchers often have high-precision parts running under water. Therefore, waterproofing the gearbox may be a problem. Parts and service for rotary ditchers can be difficult to obtain, especially for foreign-made equipment.

Safety Precautions

Because rotary ditchers can throw spoil several hundred feet to either side, the only safe locations are directly in front of and behind it. The operator's station should have a steel mesh shield and clear safety panels (e.g., Lexan, acrylic). Deflection shields are installed for protection and should be kept intact and securely fastened. Additional mud flaps may be needed and can be fabricated from rubber conveyor belting or truck flaps.

If the ditcher is hydraulic, the bypass valves must be set within the motor manufacturer's limits. On PTO-driven equipment, the slip-clutch, a safety device, must be checked to ensure that it is not stuck.

Equipment maintenance

The rotary ditcher should be equipped with "swamp" type seals. Some agricultural units may not have this outboard seal on the rotor shaft, thus allowing mud and water into the outboard bearings. Because water and grit cause excessive wear on bearings or gearsets, the gearbox oil level and condition must be checked daily. On some models, the rotor shaft bearings are separate from the gearbox and should be greased several times daily. The universal joints of PTO-driven units should be greased daily. Bolts holding the cutting edges and main rotor can loosen and should be checked frequently.

For more information about rotary ditching and ditching equipment, contact William Opp (DHRS), Jonas Stewart or Paul Haydt (East Volusia MCD), Carla Wright (Pinellas County MCD), James Robinson (Pasco MCD), Jim Hunt (Brevard MCD), Oscar Fultz (Chatham County MC Commission, Ga.).

Impounding Principles

The principle of impounding, which has been used extensively along the central east coast, is simple: keep mosquito-producing high marsh covered with a minimum of several inches of water to prevent *Aedes* from ovipositing. Due to the contour of the marsh surface, the flooding depth can vary considerably.

Before the 1970s, mosquito control considerations far outweighed natural resource interests. In the 1950s and '60s, when impoundment construction occurred, little was known about the importance of high marshes to estuarine productivity. Historically, black mangroves, *Batis* and *Salicornia* dominated many high marshes that were impounded. These plants cannot sustain continual excessive flooding to the point where the succulent plants or black mangrove pneumatophores are inundated. During those early years of impounding, water levels were maintained at depths that in some locations killed virtually all vegetation. This left some impoundments barren except for areas where red mangroves intruded.

Research. The total effects of impounding are not yet clearly understood. However, research on high marshes and impoundments since the 1950s has provided considerable information on which to base management decisions. The vast majority of the research investigating the effects of different impoundment water management programs has been partly funded by the Florida Department of Environmental Regulations' Office of Coastal Management and the Florida Department of Health and Rehabilitative Services' Office of Entomology Services.

Estuarine productivity. In many locations low marshes, with their nearly daily tidal flushings, provide more significant, continual nutrient discharges to the estuary than do high marshes. However, in locations where high-marsh acreage far exceeds low marsh, as along the Indian River lagoon, the contribution of high marsh to estuarine productivity may be very important, even though historically these high marshes were essentially dry for nine to 10 months of the year.

Provost (1967, p. 169) writes: "If it is mainly low marsh that nourishes estuaries, (these) impoundments may not be starving the estuary significantly. On the other hand, the absence of inflowing streams to nourish the estuary may render what nourishment can come from these marshes disproportionately important."

High-marsh organisms. Organisms using the high marsh can be classified into two basic groups:

- Marsh residents: those that can spend their entire life within the marsh, e.g., sheepshead minnow (*Cyprinodon variegatus*), mosquitofish (*Gambusia holbrokii = affinis*) and sailfin molly (*Poecilia latipinna*).

- Marsh transients: those that use the high marsh during a portion of their life cycle, e.g., ladyfish (*Elops saurus*), snook (*Centropomus undecimalis*

) and tarpon (*Megalops atlanticus*). Marsh transients typically enter the high marsh only during the fall high-tide period, using the marsh for food resources and as a refuge from predators during this several-month, tidal-flooding period.

Research has demonstrated that marsh residents can prosper within impoundments and serve as a potential food source for wading birds. However, impoundment dikes can interfere with high-marsh access for transient organisms. Harrington and Harrington (1961, 1982) demonstrated a decrease in the number of fish species using a marsh after impoundment, along with an accompanying change in the diet of those remaining from primarily omnivorous to detritivorous. In some instances, impounding changed heavily vegetated areas, which were previously unattractive to waterfowl, to marshes commonly used by ducks. However, until the early 1980s, little was known of the effects of various impoundment-management methods on the marsh.

Rotational Impoundment Management

Based on research findings, a rotational impoundment management (RIM) technique is currently the most favorable impoundment management technique. RIM is accomplished by installing culverts with flapgate risers through impoundment dikes to seasonally reconnect the impounded marsh with the estuary. Culverts reconnect the impoundment with the estuary by serving as "doorways" for nutrient and organism movement. Intensive sampling has shown that fish use these culverts as entrances and exits to the impounded marsh.

Culverts are strategically distributed around the dike. Favorable locations are historic, natural tidal creeks or locations where flushing will be optimized. Culvert inverts are generally set at approximately -1.0 feet NGVD (National Geodetic Vertical Datum). Culverts are left open during the fall and winter, then closed in the late spring for the mosquito-breeding season.

Spillway height is set by one of several flapgate risers designed at the minimum height necessary for mosquito control, thus allowing water levels exceeding that to spill out into the estuary. During the closure period, approximately early May through September, the impounded marsh is flooded by pumping water as needed from the adjacent estuary using either portable diesel-driven or stationary electric pumps. In early fall pumping ceases, and the culverts are opened to allow the fall high tides to flood the marsh.

RIM accomplishments

- controls saltmarsh mosquito production from the marsh with a minimum of insecticide use;
- promotes revegetation by maintaining sufficiently low water levels during the summer flooding period; and
- allows marine life to use the previously unavailable impounded high marsh.

Numerous ecosystem effects of RIM are currently under investigation. Possibly in the future, management variations such as subcells to minimize stress to impounded organisms, water-level manipulations to benefit waterfowl and endangered species, or aquaculture projects such as marine-stock enhancement can be implemented in impoundments while still maintaining their prime mosquito-control source-reduction purpose.

Operating permit

When an agency or developer wants to make structural changes to an impoundment, permitting agencies usually require long-term impoundment management improvements frequently in the form of RIM. After these structural improvements are made, the Florida Department of Environmental Regulation requires that the local mosquito control agency assume an operating permit that ensures the impoundment is managed in an environmentally acceptable manner as determined by the SOMM.

Careful consideration of water quality is important because many of the transient marine organisms entering impoundments cannot tolerate water-quality extremes. To ensure that impoundment water quality is suitable, DER requires that various water quality parameters (e.g., salinity, dissolved oxygen, turbidity, or muddiness, and temperature) be monitored both in the impoundment and adjacent estuary. If impoundment water quality is unsatisfactory, appropriate management actions, such as enhanced water exchange by flushing or overpumping, may be necessary. During culvert opening in the fall, care to minimize adverse effects to the estuary is essential.

Research and management experience will dictate how these guidelines will change over time. Current limits for the various parameters are:

- salinity must not exceed 40 parts per thousand (ppt);
- turbidity must not exceed 29 nephelometric turbidity units (NTU) above ambient;
- dissolved oxygen should not fall below 2 to 3 parts per million (ppm); and
- temperature should not exceed 36 C (97 F).

Sampling sites are determined by the mosquito control agency and DER. All measurements must be taken in the morning, when dissolved oxygen is generally lowest. Operating permit reports are submitted regularly to DER.

Impoundment Structures

Environmental permitting. Maintenance of existing impoundment structures to their original design specifications does not require permit approval. However, the construction of a new dike or the installation of new culverts requires approval by several environmental regulatory agencies (e.g., DER, Army Corps of Engineers, water management district or local county). All such work that disturbs estuarine or impoundment sediments can cause turbidity to rise, which may damage fragile marine life. Therefore, such construction requires the use of silt screens to minimize turbidity problems.

Dikes. Several major points that were important when impoundment dikes were constructed should also be considered during maintenance or construction of new ones:

- **Size.** The dike must be tall enough to prevent normal seasonal high tides from overwashing it. It must be wide enough to allow access passage of maintenance vehicles and equipment and must be sturdily built to minimize wave-action erosion.
- **Construction.** Fill must be taken from within the impoundment. When the dike course has been laid out, all vegetation, dead or alive, must be removed; any remaining plant material will weaken the dike. The dike base center consists of a trench, usually one dragline bucket wide and one deep. This core is filled with well-packed, sturdy material. When possible, leave a narrow "beach" on the estuary side. This can often be accomplished by placing the dike on the natural berm. When vegetated, this beach prevents dike erosion. Riprap placed along the beach can help trap mangrove seedlings, further stabilizing the dike. For the dike top, marl is recommended.
- **Culverts.** Culverts are generally installed with a backhoe or dragline. Because of saltwater's high corrosiveness, corrugated aluminum culverts (typically 14 gauge) are preferred. If more than one culvert is necessary in a dike section to ensure proper compaction, each must be installed separately, rather than digging one hole and placing several culverts in it side by side.

Culvert diameter depends on the water-volume exchange desired, although the larger the culvert both in diameter and length, the more difficult the installation. Experience has shown that 30 inch diameter culverts provide the necessary biological benefits and are relatively easy to install. Plastic culverts now available on the market may prove acceptable but are limited in size.

Flapgates. The following information about the advantages and disadvantages of culvert flapgate designs currently in use was provided by James R. David, Saint Lucie County Mosquito Control District.

- **Standard riser.** (Figure 3) Although the standard riser is simple to operate, it is less versatile than flapgated designs. It is quite expensive to construct (approximately $500 per structure), but is commercially available.
- **Simple flapgate.** (Figure 4)The simple flapgate is easy and inexpensive to build (approximately $50), but its lack of automatic water release is a

drawback. It can be used in combination with other flapgate types to enhance circulation.

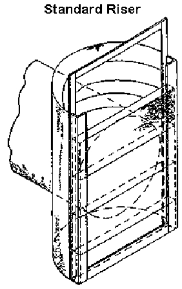

Figure 3 .

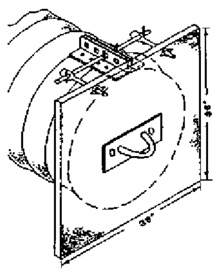

Figure 4 .

- **Flapgate riser.** (Figure 5) The flapgate riser is highly sensitive to water level variations and is easily adjustable by manipulating the riser boards. Although relatively expensive (approximately $800 to $1,000), it is commercially available.

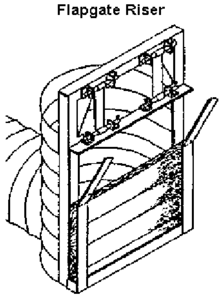

Figure 5 .

Gator Gate. (Figure 6) An all-aluminum structure fabricated by Gator Culvert is easy to open and close and fits into typical risers. If lagoon water levels exceed impoundment flooding level, water will enter impoundment while high impoundment water levels can spill out over top aluminum plate. Approximate cost: $925.

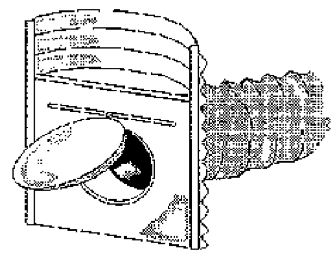

Figure 6 .

- **Modified tidegate weir.** (Figure 7) The modified tidegate weir (MTGW) is inexpensive (approximately $130), versatile (allows excess water to release automatically) and extremely sensitive to water-pressure gradients. Extra weights are necessary to reduce buoyancy during the closed period. This gate can be constructed of 3/16-inch T6 aluminum for roughly double the wooden structure's cost. St. Lucie County Mosquito Control District inverts this structure, allowing continuous drawdown of impoundment bottom water.

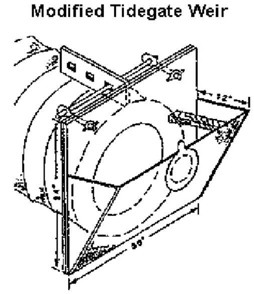

Figure 7 .

- **Weir.** A weir is a wide, low-level dam typically constructed so the height of the weir opening can be regulated by placing riser boards in it. Weirs rather than culverts are used in Louisiana and elsewhere and have been suggested for use in Florida impoundments. None have been tried to date.

Proponents suggest that because of their large surface area, weirs allow far greater water flow (hence nutrient and organism transport) than culverts during periods of high water or when totally open. However, there are serious disadvantages to weirs that have been documented. These include:

- **Vehicle transport.** After construction, weirs obstruct vehicle transport unless expensive bridges are built across them.

- **Erosion.** Weirs frequently leak, resulting in erosion that is difficult and expensive to correct.

- **Water exchange during high tides.** Because of their large surface area, weirs allow large water volumes to flow across their riser boards during extreme tides in closed periods. However, an advantage of flapgated culverts is they can open if estuarine water levels exceed those in the impoundment. Also, multiple culverts can provide the horizontal distance that weirs provide.

- **Expense.** Weirs are more expensive to install than culverts.

Summary

Since the early 1970s, we have become aware of the environmental importance of estuaries and their role in high marshes. These ecosystems support many forms of living organisms. They have their own special flora and fauna, they are breeding and nursery grounds for many kinds of marine organisms, and they can be prolific producers of saltmarsh mosquitoes. The balance of nature is always delicate, but perhaps nowhere more so than in estuaries, where the nutrient-rich brackish waters support large food chains, from microorganisms to fish, birds and mammals. Man's intrusion into estuaries has created disturbances in many ways, all of which to some extent negatively affect the estuarine balance. Mosquito-control source-reduction activities are but one of many such disturbances.

Over the past decade, we have learned through research and experience that improved salt marsh management for natural resource enhancement is possible while still maintaining the benefits of mosquito-control source reduction. RIM and OMWM using rotary ditches are valuable tools in managing Florida's sensitive salt marsh wetlands in environmentally acceptable ways while still controlling saltmarsh mosquito populations with a minimum of pesticide use. Further fine tuning may be necessary, but we have made major accomplishments in the multipurpose management of our saltmarsh resources.

Awards for Excellence

Over the past several years, two mosquito-control source-reduction programs have received high distinction from agencies responsible for wetlands resources.

U.S. Fish and Wildlife Service Conservation Service Award to Jack Salmela. Under the directorship of Leon Jack Salmela, Brevard County undertook the state's largest source reduction program. Jack's care, perseverance and success in managing these marshes for both mosquito control and wildlife resources was highlighted in 1986, when he received the U.S. Department of Interior, Fish and Wildlife Service's Conservation Service Award.

As described by the Fish and Wildlife Service: "This is the highest honor bestowed by the secretary to private citizens and groups for direct contributions to the mission and goals of the Department. It was presented to Mr. Salmela for his endless contributions to wildlife conservation through effective mosquito-control techniques and his personal dedication to effective management of wildlife resources."

Jack was further honored for his conservation efforts in 1987 when the Florida Mosquito Control Association presented him with the first Maurice W. Provost Award, an award for developing management and mosquito-control methods that reduce pesticides application while minimizing habitat alterations.

DER Secretary's Environmental Award to the St. Lucie County Mosquito Control District. In January 1990, the St. Lucie County Mosquito Control District (Frank Evans, director, Jim David, assistant director) received the Florida Department of Environmental Regulations Secretary's Environmental Award for its innovative impoundment management program. This DER award is for "wetland enhancement and management which has significantly contributed to protection, conservation or restoration of the air, water or natural resources of the state."

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