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Mosquito Control Impoundments[1]

Jorge R. Rey and C. Roxanne Connelly[2]

Introduction

A mosquito control impoundment is a salt marsh or mangrove forest with an earthen dike around the perimeter that allows the area to be artificially flooded during the mosquito breeding season (approximately May to October). The salt marsh mosquitoes *Ochlerotatus taeniorrhynchus* and *Ochlerotatus sollicitans* will not lay their eggs upon standing water. Instead, they oviposit upon moist soil; the eggs hatch when flooded by tides or rainfall and develop into adults within 5–7 days. Flooding marshes during the breeding season thus prevents oviposition and totally eliminates mosquito production from the area without having to use pesticides.

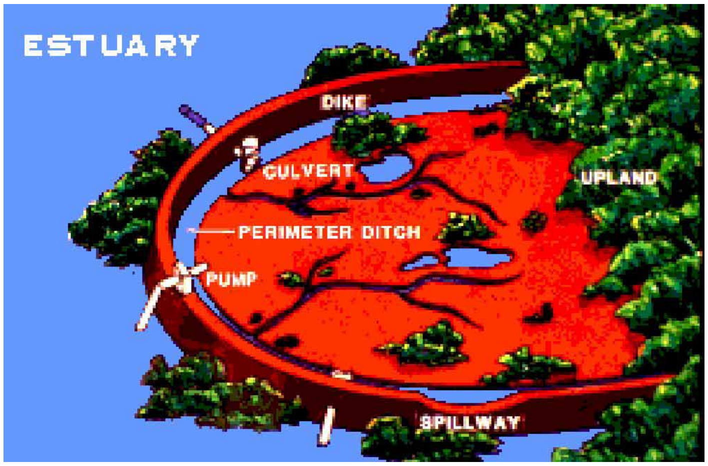

Figure 1. Impoundment schematic.

Impoundment dikes may surround the whole marsh or may stop at the upland edge. A perimeter ditch borders the dike on the inside and marks the area where material was excavated for dike construction. A number of water control structures are used to manipulate water levels within impoundments; these include pumps, culverts, spillways and weirs (Figure 1).

History

The salt marshes and mangrove forests along the east coast of Florida have, historically, been prolific breeders of salt marsh mosquitoes. Along the Indian River Lagoon, organized mosquito control was begun in the mid 1920s (Platts et al. 1943). In an effort to control these pests, hundreds of miles of parallel hand-dug ditches were constructed. This technique was soon abandoned, however, because the ditches required continuous maintenance and were not very effective in controlling mosquitoes and sandflies, partly because of the low tidal amplitude throughout most of the area.

In the 1930s, an experiment demonstrated that impounding could be an effective mosquito source reduction technique (Hull and Dove 1939). The experiment was discontinued, however, after water losses due to evaporation and seepage through the dike became excessive. By the early 1940s, the emphasis shifted to the use of DDT and other pesticides, so that by the early 1950s mosquito control in the area relied almost exclusively upon chemicals.

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2. Jorge R. Rey, professor, and C. Roxanne Connelly, associate professor, Entomology and Nematology Department, Florida Medical Entomology Laboratory, Vero Beach, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Fl 32611.

In the mid 1950s, however, pesticide resistance started to become a problem, and concerns about the toxic effects of these chemicals upon the environment started to surface. In 1954, Brevard County renewed the emphasis on source reduction and impounding, and the other counties along the Lagoon soon followed suit. By 1959, more than 3,200 ha (7,900 acres) of wetlands had been impounded (Provost 1968), and ultimately over 16,200 ha (40,000 acres) were impounded (Rey and Kain 1989), all before the mid 1970s. Most impoundments were constructed at about the mean high water mark, and initially few of them had any type of connection with the adjoining estuary. Most remained flooded and closed year-round, but some were allowed to dewater during the fall and winter

Some Effects of Impounding

Since the seventies, research has shown that impounding can have severe environmental impacts on the marshes and the adjoining estuary. Of particular concern are degradation of water quality, isolation of habitat needed by sport and commercially important fishery species during critical times in their life cycles, elimination of productive marsh vegetation, possible adverse impacts on estuarine seagrasses, and interruption of the free flow of nutrients and organisms between wetlands and the lagoon.

Within some impoundments, wetland vegetation was virtually eliminated because the impoundments were flooded to much higher levels than needed in order to compensate for evaporation and seepage (Figure 2).

Figure 2. Vegetation damage in an overflooded impoundment.

Overflooding eliminated the herbaceous halophyte (salt tolerant) cover (such as *Batis maritima*, *Salicornia virginica* and *Salicornia bigelovii*) from some of these marshes (Rey et al. 1990). Likewise, black mangroves were eliminated from some because their short pneumatophores (above-ground roots) can't withstand prolonged flooding (Figure 3).

Figure 3. Damage to black mangrove pneumatophores due to overflooding.

These effects resulted in total elimination of vegetation from some impoundments and replacement of the natural high marsh vegetation of the area (mixed black mangrove-herbaceous halophytes) with monospecific stands of red mangroves at others (Rey et al. 1990a). Primary production in impounded marshes appears to be comparable to that in unimpounded marshes but may vary significantly depending upon the management of the area in question (Lahmann 1988, Rey et al. 1990b).

Impounding also reduced the abundance and diversity of fishes using these areas. (Harrington and Harrington 1961, Gilmore et al. 1982, Rey et al. 1990). Most of the missing species were "transient species" (Snelson 1976). These are species that use the marshes and mangrove forests during only part of their life cycle. Many of the species adversely impacted by impounding, such as tarpon (*Megalops atlanticus*), snook (*Centropomus undecimalis*), ladyfish (*Elops saurus*), mullet (*Mugil cephalus*), and others are extremely important for the commercial and recreational fishery industries of the area. The aquatic invertebrate fauna of some of these wetlands were also heavily impacted by impounding; abundance and diversity patterns were changed, and in some cases the communities became more typical of inland freshwater areas than of coastal salt or brackish areas (Rey et al. 1991a, Brockmeyer et al. 1997).

Water quality and soil chemistry in many impounded wetlands degraded significantly. In some impoundments, dissolved oxygen decreased, whereas nutrient and sulfide concentrations increased. In some impoundments that were flooded by artesian wells or upland drainage, conditions

Figure 4. Pumping lagoon water into an impoundment.

became more characteristic of freshwater systems, whereas very high salinities developed in many impoundments that were flooded by pumping in Indian River Lagoon waters during the summer but then left closed without further management (Figure 4). Natural surface and pore water quality patterns in these habitats are quite complex, and determining specific impacts is equally complicated. More detailed discussion of water and soil chemistry in impounded wetlands can be found in Brockmeyer et al. (1997); Rey and Kain 1993; Rey et al. (1986, 1989, 1990b, 1991b, 1992); and Carlson et al. (1983).

Rotational Impoundment Management (RIM)

In the early 1960s, experiments with seasonal flooding of impoundments found that flooding impoundments only during the major mosquito producing season (approximately May to October) was as effective in controlling mosquitoes as year-round flooding (Clements and Rogers 1964). During the remaining part of the year, water levels inside the impoundment were allowed to fluctuate with the tides using culverts installed through the impoundment dikes. This, coupled with careful control of flooding elevations, not only permitted interchange between the marsh and the estuary but also prevented vegetation damage and replacement in many of the experimental cells.

In 1974, Jack Salmella of the Brevard Mosquito Control District and Maurice Provost of the Florida Medical Entomology Laboratory designed an impoundment project in the Banana River that incorporated an ambitious water management scheme with the stated goals of:

- Controlling salt marsh mosquitoes.
- Retaining most of the woody vegetation (mostly black mangroves).
- Permitting access to the marsh by fish and other aquatic organisms.
- Allowing adequate flushing of the impoundment.

To accomplish these goals, the impoundment design included four culverts, a spillway, and a permanent pump. During October to May, the culverts remained open and allowed interchange between the lagoon and the impoundment. During the breeding season, water levels were maintained at the minimum necessary for mosquito control. This was possible because the permanent pump allowed replacement of water losses through evaporation and seepage. Two of the culverts were equipped with flapgated risers that opened when the water levels in the Indian River were higher than in the impoundment and thus allowed further interchange, even during the "closed" summer period. The other two culverts were closed using riser boards, which could be set at a given elevation and thus allow excess water to spill over the top. These functioned in conjunction with the spillway, which was simply a low area of the dike, to prevent vegetation damage by excessively high water levels. This project, known as the Gumbo Limbo Island Project (Figure 5), was one of the last impoundments constructed along the Indian River Lagoon, and was the first to purposefully use the technique now known as Rotational Impoundment Management (RIM).

Figure 5. The Banana River project.

RIM has proven to be an extremely effective technique for minimizing adverse impacts of impounding while maintaining the capabilities to effectively control salt marsh mosquitoes. Moreover, the water management capabilities associated with active water level control in impoundments (culverts, pumps, spillways, etc.) allow the development of other management techniques designed to provide ecological benefits different from those offered by RIM.

Arguably, the most obvious benefit of hydrological reconnection is that it allows transient fish species access to the marsh during most of the year. These species use the marshes only during part of their life cycle. Repeated large catches of transient individuals in traps that sample fish passing through the culverts prove that the culverts act as effective marsh access pathways (Brockmeyer et al. 1997).

In many impoundments where the vegetation had been totally eliminated by overflooding and high salinity, simply restoring the tidal connection through culverts and monitoring flooding elevations resulted in a quick recovery of the herbaceous component (Figure 6), with mangroves lagging somewhat (Rey et al. 1990a).

Figure 6a. Vegetation eliminated by flooding and high salinity at Impoundment IRC #12.

Figure 6b. Vegetation recovery at Impoundment IRC #12.

Moreover, the water management capabilities associated with RIM have also allowed the manipulation of water levels to control exotic and upland vegetation in some impoundments, particularly in the Merritt Island National Wildlife Refuge.

Water quality improvements have also been identified in many impoundments after hydrological reconnection, particularly during the October–May open period. These include lowered nutrient concentrations, increased dissolved oxygen levels, and more "natural" salinity fluctuations. Management of excessive sulfide to prevent fish mortality has also been made possible by the use of pumps and culverts associated with RIM (Rey et al. 1992).

Impoundment Restoration

Because of the demonstrated advantages of hydrological reconnection, an aggressive program of culvert and pump installation was started in the Indian River Lagoon under the umbrella of the Florida Surface Water Improvement and Management (SWIM) Program and the Indian River Lagoon National Estuary Program. The program not only attempts to establish simple hydrological connections between the lagoon and the impounded wetland but also attempts to improve flushing and replicate tidal fluctuations by installing appropriate numbers of culverts of sufficient size at the correct locations along impoundment dikes.

In some impoundments where mosquito control can be maintained by other means or where it is no longer an issue, restoration can be advanced beyond reconnection through culverts. For example, in the 1990s, the dikes in three impoundments in Volusia County were permanently breached and mosquito control maintained via shallow ditches constructed with a rotary ditcher. Rotary ditching broadcasts the ditch spoil broadly and thus does not create the problematic spoil mounds associated with dragline ditches. Furthermore, the equipment has a very low bearing weight, so it does not produce permanent ruts or other impacts to the marsh surface. Similar projects have been undertaken by other agencies, and, as of 2011, permanent tidal exchange has been established by this method in more than 465 ha of formerly impounded wetlands (Rey et al. 2012).

A more natural (and costly) approach includes restoring the shoreline of former impoundments by backfilling the perimeter ditch—basically pushing the dike back into the ditch—with careful grading to prevent the creation of mosquito-breeding depressions. In 1998, an initial joint project involving Volusia County Mosquito Control, the St. Johns River Water Management District, and the U.S. Fish and Wildlife Service restored the shoreline of four impoundments totaling more than 93 ha in Volusia County. Again, mosquito control was maintained through a combination of directed rotary ditching and Open Marsh Water Management, which is a technique that incorporates a combination of ditches, ponds, and pond radials to eliminate mosquito-producing depressions and/or enhance access to these areas by fish that prey on mosquito larvae (Rey et al. 2012). This successful project led to additional impoundment restoration work and significant reduction in the use of pesticides.

To date, more natural hydrology has been restored in over 1,300 ha of impounded wetlands along the Indian River Lagoon, and more than 70 km of dikes have been removed. Of the original 16,185 ha of impoundments, over 12,600 have been rehabilitated in some fashion, particularly through reconnection, breaching, and shoreline restoration.

Unresolved Issues

Several issues remain important and must be considered when attempting to evaluate management alternatives for an area:

Private Ownership

One problem that often arises when trying to implement best management practices in wetlands is private ownership. In some areas, land owners have not been amenable to work on their property for fear of losing mitigation potential of closed impoundments. In other areas, mosquito control officials are hesitant to pursue re-connection or other management changes because agreements that allow mosquito management in these areas are verbal and non-binding on the owners. To solve these problems, public acquisition of impoundments is being actively pursued by a multi-agency group including the St. Johns River and South Florida Water Management Districts, the counties involved, and the Nature Conservancy.

Conflicting Mandates

Not all agencies share identical priorities, and often compromises are necessary to reconcile conflicting mandates with best management practices. For example, The U.S. Fish and Wildlife Service manages the Merritt Island and the Pelican Island National Wildlife Refuges to provide habitat for migratory waterfowl, wading birds, and shore birds. This often requires that impoundments be closed during periods not required by mosquito control. However, all agencies involved are actively cooperating to implement ecologically sound compromises that maximize tidal connection while satisfying the mandates of the USFWS and mosquito control agencies.

Alternative Management

Perhaps the most difficult management issue is implementation of alternative management practices at a site when management practices conflict with the overall goal of marsh lagoon re-connection. Examples of these include temporarily closing an impoundment with heavy bird use in the fall to enhance feeding opportunities for the birds, or maintaining an impoundment closed because it receives heavy runoff or treated water. Research has demonstrated environmental benefits of many of these alternative management practices, but given our state of knowledge the trade-offs are difficult to estimate.

One school of thought proposes that the prudent approach is to implement such management only under exceptional circumstances because the alternative results in more "natural" conditions and many benefits have been documented. On the other hand, some suggest that given the extreme impacts to the lagoon caused by human activities and the many gaps in our knowledge of the patterns and processes now regulating this system (let alone historical ones), we should introduce variety in management to address some of the unknowns, and we should take advantage of the water management capabilities provided by mosquito impoundments to mitigate some of the known adverse impacts.

Other factors complicating the issue include questions on how realistic and desirable it is to attempt to restore conditions to those existing in the lagoon 100 years ago, and on how much marsh-lagoon exchange actually took place before man's impact (many natural marshes have fronting berms that effectively isolate them from the estuary, at least during parts of the year). Some consider that implementation of management strategies other than RIM are only for the benefit of specific groups of species (such as wading or migratory birds) to the exclusion and perhaps harm of other species, while others argue that other strategies are no different from RIM in that they can provide a plethora of benefits, some of which may be different from those provided by RIM.

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