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Part II

STUDIES OF IMPOUNDING FOR THE CONTROL OF SALT-MARSH MOSQUITOES IN FLORIDA, 1958–1963[1]

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Hull *et al.* (1939) reported encouraging results with impounding for the control of sand flies (*Culicoides*) and *Aedes* mosquitoes in a salt marsh in Florida, but the project was short lived owing to excessive loss of water from the impoundment. In the early nineteen fifties, the Brevard County, Florida Mosquito Control District initiated a program of impounding salt marshes for the control of floodwater mosquitoes, *Aedes taeniorhynchus* and *Aedes sollicitans*. In 1958 the Entomological Research Center of the Florida State Board of Health, in cooperation with the Indian River Mosquito Control District, initiated a long-term study of water management methods for mosquito control in impounded salt marshes at Vero Beach. The objectives of this study were: (1) to determine the most economical, effective method of water management for mosquito control in impounded salt marshes; (2) to observe the effects of the various management practices on other animals and plants in the marsh. This is a report of the results of this study during the five-year period 1958 through 1963.

DESCRIPTION OF STUDY AREA. The study area was a typical mangrove-saltwort (*Batis maritima*) marsh, 80 acres in size, located along the western shore of the Indian River. This marsh originally was impounded with a peripheral dike by the Indian River Mosquito Control District in 1956. It was necessary to select this previously diked area for the study since all marshes in this area suitable for the study had been diked by 1957.

Dikes were constructed to partition the impounded marsh into nine plots of approximately 8 acres each (Fig. 2). Automatic tide gates and a 6-inch artesian well were installed prior to the first flooding of the plots, which was on November 24, 1958. The artesian well furnished water to six of the nine plots from a narrow reservoir at the west end of the plots. Water from the reservoir flowed by gravity into the plots through manually operated sluice gates.

The nine plots were grouped into three blocks with each block containing three randomized treatments. The treatments were (1) yearlong flooding only with artesian water; (2) seasonal flooding: controlled flooding with artesian water from March 15 until the fall tides first flooded the marsh, usually around the fall equinox. From this time until the following March 15, tide gates were open continually; and (3) tidal flooding: dikes were breached to simulate natural marsh flooding. The latter treatment was designed originally to

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demonstrate the mosquito breeding potential of an untreated marsh; however, it did not prove satisfactory for this purpose because of over-drainage. Therefore, two adjacent salt-marsh islands that were not diked and one small marsh on the mainland were used as untreated checks for the study. Data also were obtained at irregular intervals from nearby impoundments having no water management program and only rainfall for flooding.

Methods. Treatment effects on mosquito production, except *Mansonia,* were determined by larval dipping. At each sampling period, 5 dips were taken at each of 20 stations. The dipping schedule for each of the treatments was as follows: permanently flooded plots were dipped quarterly in the months of March, June, September, and December; the seasonally flooded plots were dipped in March and June, and prior to tidal flooding in September. When these plots were flooded only by tides they were dipped bi-weekly. The seasonally flooded plots and all check plots also were dipped at other times when conditions indicated potential breeding of flood-water mosquitoes.

Mansonia mosquitoes were sampled by use of larval traps (Bidlingmayer, 1954). Traps were set in the permanently flooded plots during June to July and November to January. In the seasonally flooded plots, traps were set only in July and August, which was near the end of the period during which these plots were flooded with artesian water (Fig. 1).

Water samples for salinity readings were collected each month from three locations in each plot, and two locations in

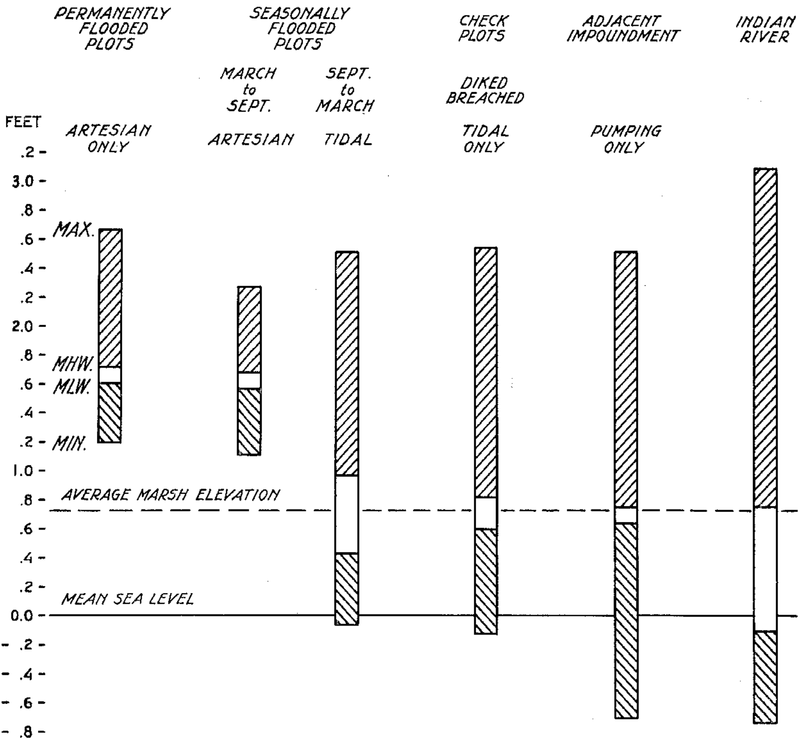

Fig. 1.—Water levels in experimental plots, adjacent impoundment, and Indian River at Vero Beach, Florida, 1959–1963.

the reservoir and the adjacent Indian River. Maximum-minimum water levels were recorded with gauges three times weekly in all plots, the Indian River, and adjacent marshes (Fig. 1). Treatment effects on vegetation were determined by taking photographs annually at permanent stations in each treatment. Effects on wildlife were studied by others, and these data will be reported elsewhere.

MOSQUITO PRODUCTION. Treatment effects on mosquito production from January, 1959 through December, 1963 are shown in Table 1. The larval data from the permanently flooded plots are based on 9,355 samples and show, as expected, that flooding yearlong eliminates the production of flood-water mosquitoes. Since this treatment was flooded only with artesian water, a variety of fresh-water species was collected in these plots but none in large numbers. *Culex salinarius* and *Anopheles crucians* comprised more than 75 percent of all collections in this treatment. Similar results in fresh-water impoundments were noted by Chapman and Ferrigno (1956) in New Jersey, and by Darsie and Springer (1957) in Delaware. A total of 476 trap settings for *Mansonia* were made over a variety of fresh-water plant species, principally cattail (*Typha* sp.) in the permanently flooded plots. Collections were fewer than one *Mansonia* larva per sample. In cattail, each sample included from one to three clusters of roots. No *Mansonia* were found on the other plants sampled.

Data for seasonal flooding are presented in two distinct periods in Table 1. The average number of .77 larva per sample during artesian flooding and .32 larva per sample during tidal flooding are results from 5,975 and 4,040 samples, respectively. It should be noted that the *Aedes* larvae, comprising more than half of the collections during the period of artesian flooding, resulted from the initial flooding in March. Usually these plots were dry just prior to this time, the high-tide season having ended in December or January (Fig. 1); therefore, *Aedes* eggs were present on the marsh when the tide gates were closed for the first annual flooding with artesian water. No *Mansonia* larvae were found in 159 samples taken over a period of three years in the seasonally flooded plots.

The data titled "rain flooding only" (Table 1) were obtained in 1959 from a 60-acre impoundment adjacent to the experimental area. This impoundment was sampled only for *Aedes* larvae in relation to the testing of larvicides and is included to reflect the breeding potential of an impoundment having no water control structures or water supply except rain. Water level data are not available for this impoundment, but it was observed that the marsh was intermittently dry and flooded by rains during the period of sampling.

As stated previously, the plots having breached dikes were over-drained and proved unsatisfactory as untreated checks for mosquito production. Data from the undisturbed salt marshes are shown in the last line of Table 1. The data are based on 3,435 samples taken on the same schedule as that of the experimental plots. These data show the mosquito breeding potential of a natural salt marsh having no water management except old handmade ditches, which are present in all marshes in this area but are not maintained.

Considering the many factors that influence the kinds and numbers of mosquitoes found in a particular marsh, any effect of salinity on the mosquitoes produced in the various treatments in this study is not apparent. The average water salinity in the various treatments is shown in Table 1. The average salinity of the Indian River was 29.6 parts per thousand. The lower salinities in the plots during periods of tidal flooding might have resulted from fresh-water seepage from the upland and adjacent fresh-water plots and the effects of rainfall on the diked area; however, data are not available to confirm this.

VEGETATION. Salt marsh plants showed a wide variation in their reactions to the treatments applied in this study. Figures 2 and 3 show the overall changes in the

TABLE 1.—Effects of various methods of water management on the control of mosquitoes in salt marshes at Vero Beach, Florida, January 1959–December 1963.

	Average number of larvae per sample[1]													Average salinity
		Aedes		*Culex*			*Anopheles*				*Uranotaenia*		*Mansonia*	
Treatment	All genera except *Mansonia*	*taeniorhynchus*	*sollicitans*	*salinarius*	*nigripalpus*	(Mel.) *erraticus*	*atropos*	*crucians*	*bradleyi*	*quadrimaculatus*	*lowii*	*sapphirina*	*perturbans*	Parts per thousand
Diked:														
Permanent flooding artesian water	.88	0	0	.41	.06	.03	.02	.25	.01	.01	.09	<.01	.33	2.7
Seasonal flooding														
March–Sept., artesian	.77	.07	.48	.10	<.01	0	.02	.01	.03	0	.06	<.01	0	5.0
Sept.–March, tidal	.32	.15	.08	<.01	.01	0	.06	.02	<.01	0	0	0	..	21.2
Rain flooding only[2]	87.37	81.26	6.11	..	..	..	..	..	..	..	..	..	..	..
Dikes breached, tidal	.73	.17	.49	.02	<.01	0	.05	<.01	<.01	0	0	0	..	17.1
Not diked: (check)[3]	30.42	18.04	12.14	.02	.08	.04	0	.02	.04	0	.04	0	..	..

[1] One dip or one trap setting. [2] Sampled only during 1959. [3] Sampled only during 1961–1963.

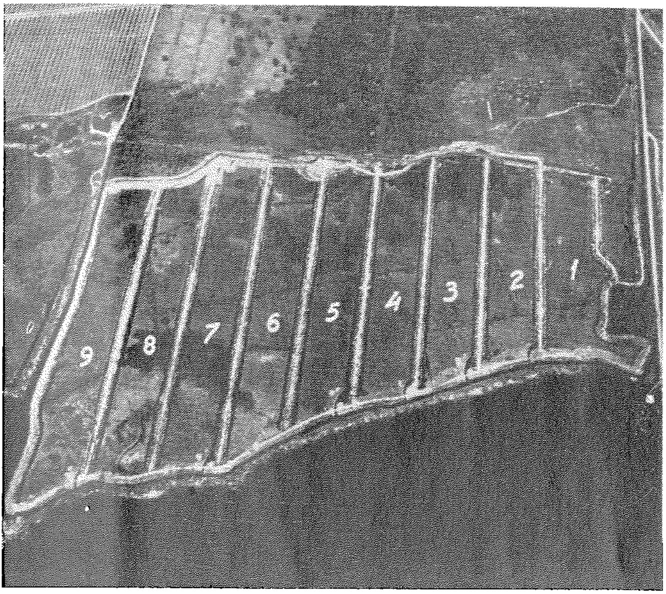

FIG. 2.—Pre-treatment condition of plots, 1958. Plots 2, 4, 7—permanent flooding; plots 3, 5, 9—seasonal flooding; plots 1, 6, 8—dikes breached, tidal.

FIG. 3.—Condition of plots in 1963, showing five-year response of vegetation to the various treatments.

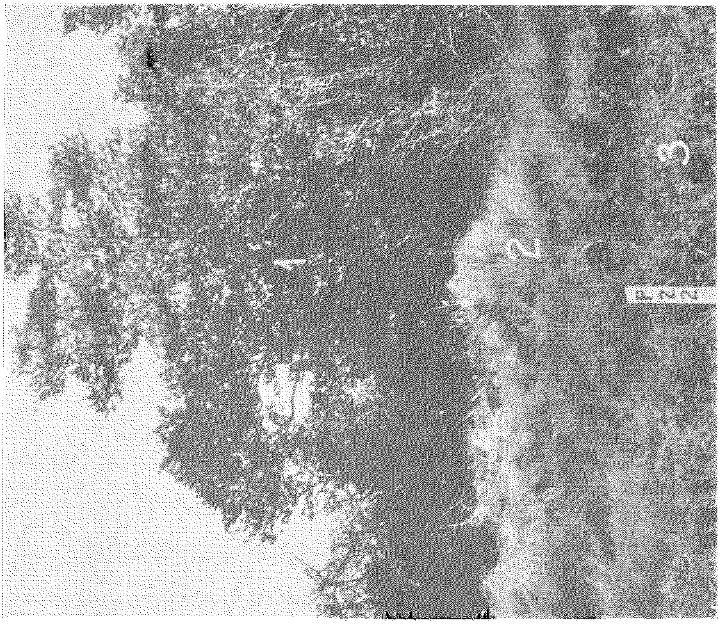

FIG. 4.—Typical salt-marsh vegetation in permanently flooded plots prior to flooding with artesian water, 1958: (1) Black mangrove; (2) salt grass; (3) saltwort.

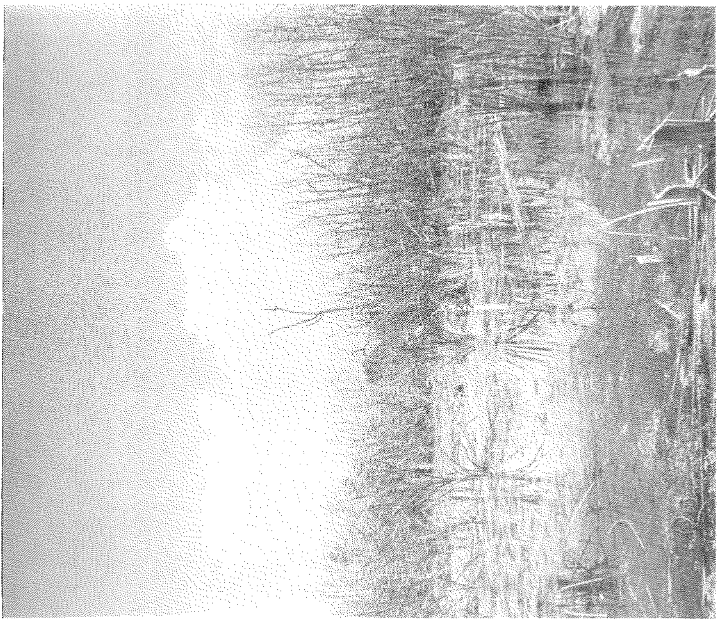

FIG. 5.—Same view as in Figure 4 after five years of continuous flooding, 1963: Black mangrove (dead); salt grass and saltwort replaced by cattail.

experimental area during the five-year period.

Fifteen genera of plants were observed and photographed yearly. In plots flooded yearlong (Figs. 4 and 5), black mangrove, *Avicennia nitida,* and saltwort, *Batis maritima,* were killed in two years; salt grass, *Distichlis spicata,* was killed in three years and was replaced by cattail; white mangrove, *Laguncularia racemosa,* was damaged initially but adjusted and continued to thrive; red mangrove, *Rhizophora mangle,* appeared not to be damaged; woody glasswort, *Salicornia perennis,* was completely eliminated in the second year and sea ox-eye, *Borrichia frutescens,* in the third year of this treatment.

In the seasonally flooded plots (Fig. 6 to 9), black mangrove was severely damaged but was not killed during the period of this study; sea ox-eye appeared not to be affected by this treatment; woody glasswort and saltwort were eliminated in the second year; salt grass was not killed but propagation appeared to be retarded; cattail gradually replaced the saltwort but propagation was much more retarded than in the permanently flooded plots. There were no visual changes in vegetation in the plots having breached dikes during this study.

Cattail was by far the dominant species invading the permanently flooded plots, which were flooded only with rain and artesian water. Other plants that became established in these plots were widgeon grass, *Ruppia maritima;* bulrush, *Scirpus* sp.; duck weed, *Lemma* sp.; spikerush, *Eliocharis* sp.; and two submerged species, *Najas marina* and an alga, *Chara aspera.* Cattail also was the dominant species invading the seasonally flooded plots but was never dominant over salt-marsh plants as it was in permanently flooded plots. The only other fresh-water or brackish water plant recorded in the seasonally flooded plots was widgeon grass.

In the fall of 1963, one of the permanently flooded plots that was overgrown with cattail was opened to tidal flooding. Figure 10 shows the cattail in this plot during artesian flooding; Figure 11 shows the same area four months after the plot was opened to tidal flooding. During this period of tidal flooding, water salinities ranged from 24 to 29 parts per thousand in this plot, whereas the maximum was 3.3 during nine months prior to tidal flooding.

FISH AND WILDLIFE. Wildlife studies conducted by others in these plots (unpublished) indicate that seasonal flooding generally is more beneficial to birds than permanent flooding or natural marsh conditions. Similar findings were reported by Provost (1959). Also, this treatment will permit the movement of fish between tidal marshes and the Intracoastal Waterway during the season of high tides (September to December). How important this might be to the maintenance of fish populations is not known to the authors at this time.

WATER LOSS AND REPLACEMENT. Data on water loss and replacement in the two flooding treatments are shown in Table 2. These data show that the plots flooded yearlong lost an average of 8.01 feet (96.12

TABLE 2.—Water loss and replacement (in feet) to maintain an average depth of approximately one foot above marsh level in impounded salt marshes at Vero Beach, Florida, 1960–1963.

	Water loss			Annual replacement by			
		Annual		Rainfall		Other Sources	
Treatment	Daily Average	Average	Range	Average	Range	Average	Range
Permanent flooding	.022	8.01	6.30–9.65	3.34	2.27–4.25	4.67	2.05–7.38
Seasonal flooding (March–Sept.)	.021	3.95	3.04–5.21	2.13	1.16–3.22	1.82	.62–4.05

[1] Ninety-one percent of recorded rainfall at the experimental site was reflected by water level gauges in permanently flooded plots and 98 percent in seasonally flooded plots.

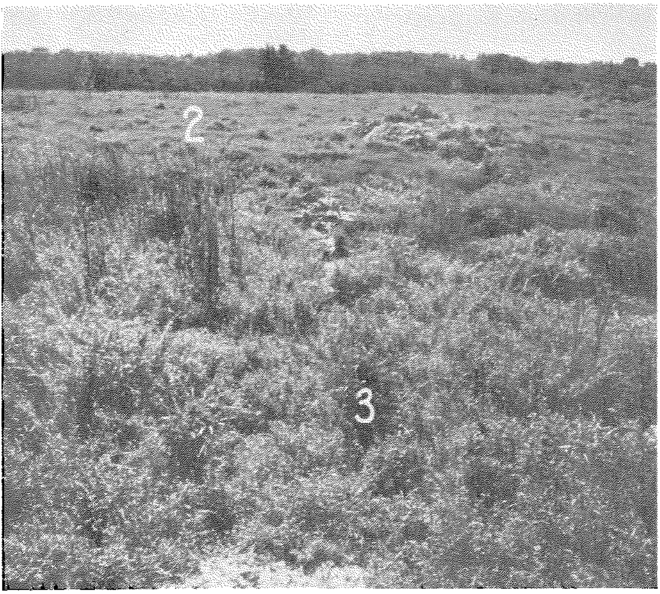

Fig. 6.—Typical salt-marsh vegetation in seasonally flooded plots prior to initial flooding, 1958: (2) salt grass and (3) saltwort. (Cattails were present before study began owing to effects of diking by mosquito control district in 1956.)

Fig. 7.—Same area as in Figure 6 after five years of seasonal flooding, showing saltwort replaced by cattail and (2) salt grass retarded but continuing to live, 1963.

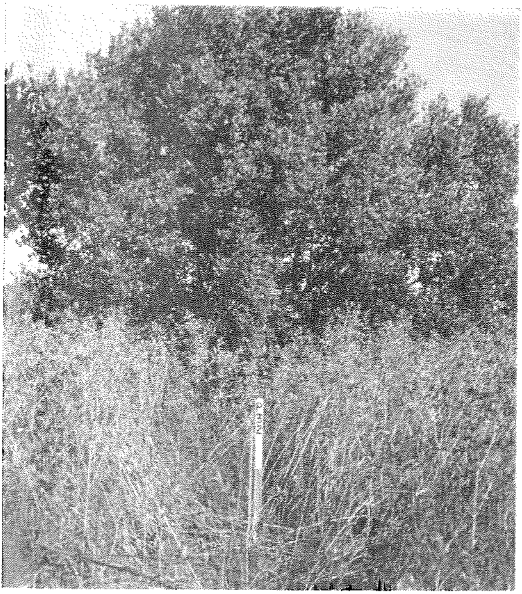

FIG. 8.—Typical black mangrove in seasonally flooded plots prior to initial flooding, 1958. Note sea ox-eye in foreground.

FIG. 9.—Same black mangrove as in Figure 8, alive but severely damaged after five years of seasonal flooding, 1963. Sea ox-eye continues to thrive.

FIG. 10.—Cattails in Plot 4 after four years of continuous flooding with artesian water. (Note *Lemna* around water level gause, 1962.)

FIG. 11.—Same scene as Figure 10 after four months of tidal flooding, 1962.

inches) per year or .022 foot per day. An average annual rainfall of 3.34 feet (40 inches) was recorded in the experimental area, thus requiring an average annual water replacement of 4.67 feet (56.04 inches) from other sources to maintain an average depth of approximately one foot above marsh level in this treatment. In the dryest year, 7.38 feet (88.56 inches) of water from other sources were required to maintain flooding in the permanently flooded plots.

The average water replacement from other sources in the seasonally flooded plots (March to September) was less than one-third that required in the permanently flooded plots and in the dryest year was only 4.05 feet (48.6 inches). However, it should be pointed out that tides were excluded from the permanently flooded plots. Had the tide gates been allowed to function in these plots, flooding could have been maintained with tide water at least from September through December. Therefore, the economy of seasonal flooding over permanent flooding would not be as significant under this procedure as the data might indicate.

Sixty-three percent of the average annual rainfall in this area occurs between March and September. This is a distinct advantage to impounding, because normal tides do not flood the marshes during this period on the East Cost of Florida. Therefore, these two natural resources of water for impounding are seasonally complementary in this area.

Discussion. The results of this study show that salt-marsh *Aedes* mosquitoes can be controlled effectively on the East Coast of Florida by flooding salt marshes yearlong, or only seasonally from March through August or early September. Frequent tidal flooding and lower temperatures result in adequate control of salt-marsh *Aedes* in this area during October through February.

None of the flooding treatments in this study resulted in a serious problem from fresh-water mosquitoes, even the treatment flooded yearlong with artesian water. Although cattail invaded these plots in abundance and produced a small population of *Mansonia* mosquitoes, results in the seasonally flooded plots indicate that both the cattail and *Mansonia* mosquitoes can be controlled in plots flooded yearlong by utilizing automatic tide gates that would permit flooding with salt water during periods of seasonal high tides and wind tides.

Seasonal flooding has some economic advantage over yearlong flooding, as it is necessary to supply water to the latter treatment from a supplementary source in the spring (December to March). However, where sand flies (*Culicoides*) constitute a problem, yearlong flooding is required for the control of this pest (Rogers, 1962). Generally, seasonal flooding also appeared to be more favorable for birdlife than the other treatments.

This study showed that rainfall alone is not adequate for flooding salt marshes for effective mosquito control on the East Coast of Florida. In fact, large broods of salt-marsh *Aedes* were hatched in adjacent impounded marshes having no water control structures during the period of this study. Therefore, diking without use of tide gates, pumping, or other sources of water might increase rather than reduce the production of flood-water mosquitoes in these marshes.

Actually, it has been shown in practice by control districts that tides and rainfall together are not adequate for maintaining an impoundment yearlong. This is especially true in abnormally dry years and at locations several miles away from ocean inlets. Therefore, other sources of water will be necessary for the most effective use of impounding for mosquito control on the East Coast of Florida. Even so, impounding is the most effective, economical method of source reduction for salt-marsh *Aedes* and *Culicoides* known for this area of Florida at this time. Moreover, impounding appears to be regarded with favor by wildlife interests.

If the initial flooding in seasonal impoundments could be delayed until near the end of the dry season (May or June) this treatment would be even more attractive with respect to costs. Some observations will be made on the feasibility of this plan during 1964.

The data and conclusions from this study are applicable only to the East Coast of Florida, where normal tides do not flood salt marshes during the summer. Limited studies with impounding on the Gulf Coast of the State, where tides frequently flood salt marshes between April and September, have not been encouraging. Additional studies will be necessary in order to assess the value of impounding on the West Coast of Florida.

ACKNOWLEDGMENTS. The authors gratefully acknowledge the many contributions of Mr. E. J. Beidler, Director, and the Commissioners of the Indian River Mosquito Control District to this study. Without the assistance of the District in constructing dikes, supplying the artesian well, and in maintaining the dikes, this study would not have been possible.

References

BIDLINGMAYER, W. L. 1954. Description of a trap for *Mansonia* larvae. Mosquito News 14(2): 55–58.

CHAPMAN, H. C., and FERRIGNO, F. 1956. A three-year study of mosquito breeding in natural and impounded salt-marsh areas in New Jersey. Proc. New Jersey Mosq. Ext. Assoc. 43:48–64.

DARSIE, R. F., JR., and SPRINGER, P. F. 1957. Three-year investigation of mosquito breeding in natural and impounded tidal marshes in Delaware. Delaware Agr. Exp. Sta. Bull. (Tech.) 320:65 pg.

HULL, J. B., DOVE, W. E., and PLATTS, N. G. 1939. Experimental diking for control of sand fly, and mosquito breeding in Florida salt-water marshes. Jour. Econ. Ent. 36(3):405–9.

PROVOST, M. W. 1959. Impounding salt marshes for mosquito control—and its effects on bird life. The Fla. Naturalist 32(4):8 pg.

ROGERS, A. J. 1962. Effects of impounding and filling on the production of sand flies *(Culicoides)* in Florida salt marshes. Jour. Econ. Ent. 55(4):521–27.

ERADICATION OF *AEDES AEGYPTI* IN LATIN AMERICA

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In 1947 the Pan American Sanitary Bureau was charged with the responsibility for the coordination of the *Aedes aegypti* Eradication Campaign in the Americas. As of December 1963 the eradication of *Aedes aegypti* from 17 countries and territories in the Americas had been certified, with Argentina apparently about to be added to the list as the 18th country.

But this was an eradication campaign, and eradicators can never rest on the laurels of what they have accomplished as long as the task they have undertaken is incomplete. Instead, attention and effort must be focused on what remains to be done. In Figure 1 it may be seen that success has been attained in Mexico, all of Central America, and all of South America except what may be called its Caribbean Coast. There is trouble in the Caribbean, and the situation there is not so good as it was five years ago. Several territories from which *aegypti* had been eradicated have been reinfested. The earlier *aegypti* appeared to be DDT-susceptible; the reinvaders are definitely DDT-resistant, and often dieldrin-resistant, too.

The problem is complex in the Caribbean not only because of biological factors, but also because of economic and administrative ones.

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