THE FAILURE OF *GAMBUSIA PUNCTICULATA* AND OTHER MINNOWS TO CONTROL *AEDES TAENIORHYNCHUS* IN A MANGROVE SWAMP ON GRAND CAYMAN, W.I.

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ABSTRACT. For 3 years (1972–75) the numbers of *Gambusia puncticulata* and other minnows in a Grand Cayman mangrove swamp were monitored by daily trapping. Concurrently the swamp's water levels were measured and the occurrence of immature *Aedes taeniorhynchus* recorded. The minnows were unable to control this mosquito due to 3 effects of flooding: 1) immediate hatching of mosquito eggs, 2) dilution of the minnow population and 3) delayed increase in *G. puncticulata* numbers and lack of increase among other minnow species. Additionally, fish numbers were greatly reduced whenever the swamp drained.

INTRODUCTION

Minnows of the genus *Gambusia* are among the most effective predators of mosquito larvae and pupae. *Gambusia affinis affinis* Baird and Girard and *G. a. holbrooki* Girard have been used successfully as larvivores in a variety of habitats and against a range of species (Hildebrand 1919, 1921; Sokolov and Chvaliova 1936; Krumholz 1948; Rees, Bown and Winget 1969; Tabibzadeh et al. 1970; Hoy and Reed 1970, 1971; Farley and Younce 1977; Green and Imber 1977). Apart from Harrington and Harrington (1961) and Nakagawa and Ikeda (1969), little has been published upon the use of *Gambusia* species in transient-flooded habitats. Because of the well-documented efficacy of other members of the genus, the possible use of indigenous *G. puncticulata* Poey against *Aedes taeniorhynchus* Wied. was investigated *in situ* in a mangrove swamp on the island of Grand Cayman. This work involved sampling the minnow population by trapping, recording the occurrence of immature *Ae. taeniorhynchus* and measuring swamp water levels during each rain and/or tidal flooding.

MATERIALS AND METHODS

STUDY AREA. Grand Cayman is a small, low-lying island between Cuba and Jamaica. The island's geology and topography are given by Matley (1926) and Brunt et al. (1973). The climate is dominated by a summer wet season and a winter dry season. The island's vegetation is summarized by Johnston (1975). About half of the island is covered with mangrove swamps (Davies and Giglioli 1977). Three species of mangrove are present; red (*Rhizophora mangle* L.), black (*Avicennia germinans* L.) and white (*Laguncularia racemosa* Gaertn). Buttonwood (*Conocarpus erectus* L.) also occurs. There is no clear zonation of species, except for the pure stands of *R. mangle* along the seaward fringes of the swamps. Saltwort (*Batis maritima* L.) is the commonest herb in the swamps and is often found with *A. germinans.* Since the swamps lie at or near sea level, they are easily flooded by high tides and/or rain. Despite their general flatness, these swamps have many temporary pools and a few permanent ones. The swamp waters are brackish except after heavy rain. The study area was in the northwestern end of the island; Fig. 1 gives its location, vegetation and trap sites. This area is referred to as Salt Creek swamp.

FISH. The design of the minnow traps is shown in Fig. 1. Traps were baited with bacon and set with the 1.3 cm diam entrances just submerged. Traps were set within a day of the sites becoming flooded and were emptied daily by removing the funnels. Catches were sorted in the field by species, sex, breeding condition and body length (minus caudal fin). A line of 7 traps was set along a road through Salt Creek swamp, allowing an accessible cross section to be trapped (Fig. 1). Water levels were measured daily from the tops of pipes sunk in the swamp floor, at sites 1a, 2a and 3. These measurements gave relative water levels at the time of each visit. When the swamp drained, water levels were measured by digging down to the water table. Flood levels were established by relating observed floodings to measured levels. Daily levels were converted to weekly means.

MOSQUITOES. The presence of *Ae. taeniorhynchus* larvae and pupae was recorded at the trap sites when catches were sorted. Emergence of adult mosquitoes was also noted at these times. No attempt was made to count mosquitoes; they were only recorded as present or absent and their stage of development noted.

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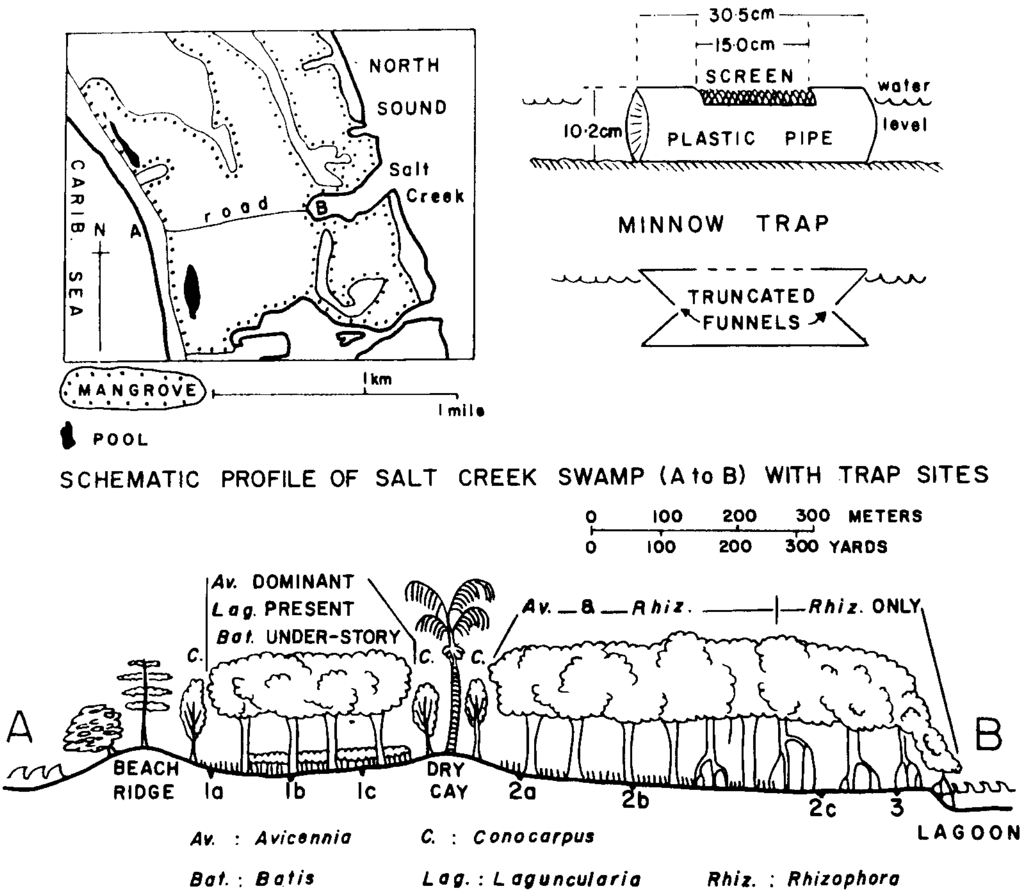

Fig. 1. Location, vegetation and trap sites of Salt Creek swamp with design of traps.

RESULTS

MOSQUITOES. The chronology of appearance of the aquatic stages of *Ae. taeniorhynchus* as a function of flooding duration at Salt Creek is presented in Table 1. Most larvae and pupae (87.2%) were found within the first 9 days of flooding, with adults normally emerging after 7–11 days. Larvae were rarely observed on the first day of flooding because small first stage larvae were difficult to find. Figures 2, 3 and 4 show that immature *Ae. taeniorhynchus* were most frequently found shortly after the onset of the main inundation of each wet season. The few larvae persisting beyond 11 days were stragglers and rarely reached adulthood. In 1975 mosquito larvae were also found long after the start of the main flooding at site 2a (Fig. 4). These larvae presumably hatched from eggs laid during two dry periods following partial drainage of the surrounding swamp.

Since the majority of mosquito immatures were present only during the first 11 days of flooding, the time available for predation by minnows was greatly restricted.

FISH. When Salt Creek water levels were at their lowest, there were only 2 possible reservoirs for the minnows; the fringe of the lagoon and one permanent pool (Fig. 1). Inundation of the swamp expanded its surface area by as much as 143 times (from the 0.7 ha pool to ca. 100 ha). The swamp's elevation changed little with distance; trap site 1a lay only 2 cm above site 3, even though they were 906 m apart. Consequently, even small rises in the water level could rapidly flood large areas. Thus a 10 cm rise at site 1a, when dry, was sufficient to flood it with a sheet of water. Complete flooding of Salt Creek swamp took from 1 to 14 days during the period of study.

Rises in water level which were insufficient to cause sheet flooding did expand existing pools and create new ones. Fish in these expanded pools were unable to reach *Ae. taeniorhynchus*

Table 1. Occurrence and duration of *Ae. taeniorhynchus* larvae and/or pupae with flooding, at Salt Creek (1973–75).

Flooding duration (days)	Days *Ae. taeniorhynchus* found	
	Larvae and/or pupae	Adult emergence
1	3	0
2	27	0
3	36	0
4	49	1
5	50	0
6	50	0
7	24	0
8	26	4
9	14	8
10	9	3
11	11	2
12	4	0
13	2	0
14	2	1
15	1	0
16	3	0
17	1	0
18	1	0
19	1	0
20	2	0
21	2	0
22	2	0
23	0	0
Totals	320	19

immatures in the newly formed, adjacent ones, so that these larvae were safe from predation.

Trapping continued from October 1972 until December 1975 at sites 1a, 2a and 3 while sites 1b, 1c and 2b were trapped from May 1973 until December 1974. Three species of fish were regularly caught: *Gambusia puncticulata* Poey, *Limia caymanensis* Rivas and Fink and *Rivulus marmoratus* Poey. More *G. puncticulata* were captured (10,048) than any other species. The totals for *L. caymanensis* and *R. marmoratus* were 5,826 and 560, respectively. Fifty-four *Cyprinodon variegatus variegatus* (Lacépède), the sheepshead killifish, were also taken. Laboratory studies in Cayman confirmed that all 4 species were larvivorous. The last 3 species merit only brief consideration as control agents since they were captured in relatively small numbers.

Gambusia puncticulata catches were summarized as weekly totals in Figures 2, 3 and 4. Catches from sites 2c and 3 were excluded since they were negligible. These totals were from the first 10 weeks of the main flooding of each wet season. This minnow was scarce in the traps during the initial 5 weeks of each inundation as compared to the second 5 weeks. *Gambusia puncticulata* was especially infrequent at all sites during the first 2 weeks of flooding, with catches averaging 0.3 ± 1.2 (206 trapping days), compared with the following 8 weeks, when mean catches were 2.8 ± 5.6 (797 trapping days). These means were significantly different ($P < 0.001$, Snedecor and Cochran 1957). The large standard deviations reflected the wide variation in daily catches; this was so throughout the trapping program. These figures emphasize the scarcity of *G. puncticulata* during the early stages of flooding, when the majority of *Ae. taeniorhynchus* were completing their vulnerable, aquatic development.

Catches of *Limia caymanensis* did not increase as greatly or as consistently as those of *G. puncticulata*. *Rivulus marmoratus* catches showed no increase and rarely were more than one caught at a time.

At the end of the wet season the swamp gradually drained, causing its standing water to shrink from a continuous sheet to isolated pools and, finally, to a single pool. This drastic reduction in the habitat of the minnows greatly reduced their numbers. Overcrowding was observed at the trap sites and catches were correspondingly high. An indication of this fall in fish numbers was given by the mean daily catches of *G. puncticulata* (from all sites except 2c and 3). These catches were 11.2 ± 15.9 (107 trapping days) over the last 10 days of each wet season flooding, but were only 1.2 ± 2.5 (101 trapping days) over the first 10 days of subsequent dry season floodings. These means were significantly different ($P < 0.001$, Snedecor and Cochran 1957).

Dry season inundations were usually briefer than those of the wet season, thus preventing such large increases in *G. puncticulata* numbers, while allowing broods of *Ae. taeniorhynchus* to emerge and fly off. Seasonal drainage of the swamp reduced minnow numbers so that few were present when the next hatch of these mosquitoes occurred.

DISCUSSION

Immature stages of *Ae. taeniorhynchus* were largely confined to the start of each flooding; this was probably due to this species' habit of ovipositing upon the damp, non-flooded substrates of mangrove swamps and not upon standing water. During the late wet season much of the mangrove was flooded, which greatly restricted the area available for egg laying. When the mangrove drained at the end of the wet season, extensive oviposition was possible and could continue for as long as adults were present. Eggs of this species can resist desiccation for up to 6 months (Bidlingmayer and Schoof 1956) and could therefore accumulate throughout the dry season. When the mangrove subsequently flooded these eggs would hatch, producing high densities of larvae.

Another result of flooding was a considerable dilution of the small number of minnows present at the beginning of the wet season. This dilution undoubtedly reduced the predatory ability of these fish.

The increase in *G. puncticulata* numbers at the start of the wet season was apparently delayed. Catches of *G. affinis* from rice fields are initially small but increase greatly 4–6 weeks after being stocked (Reed and Bryant 1974, 1975). The

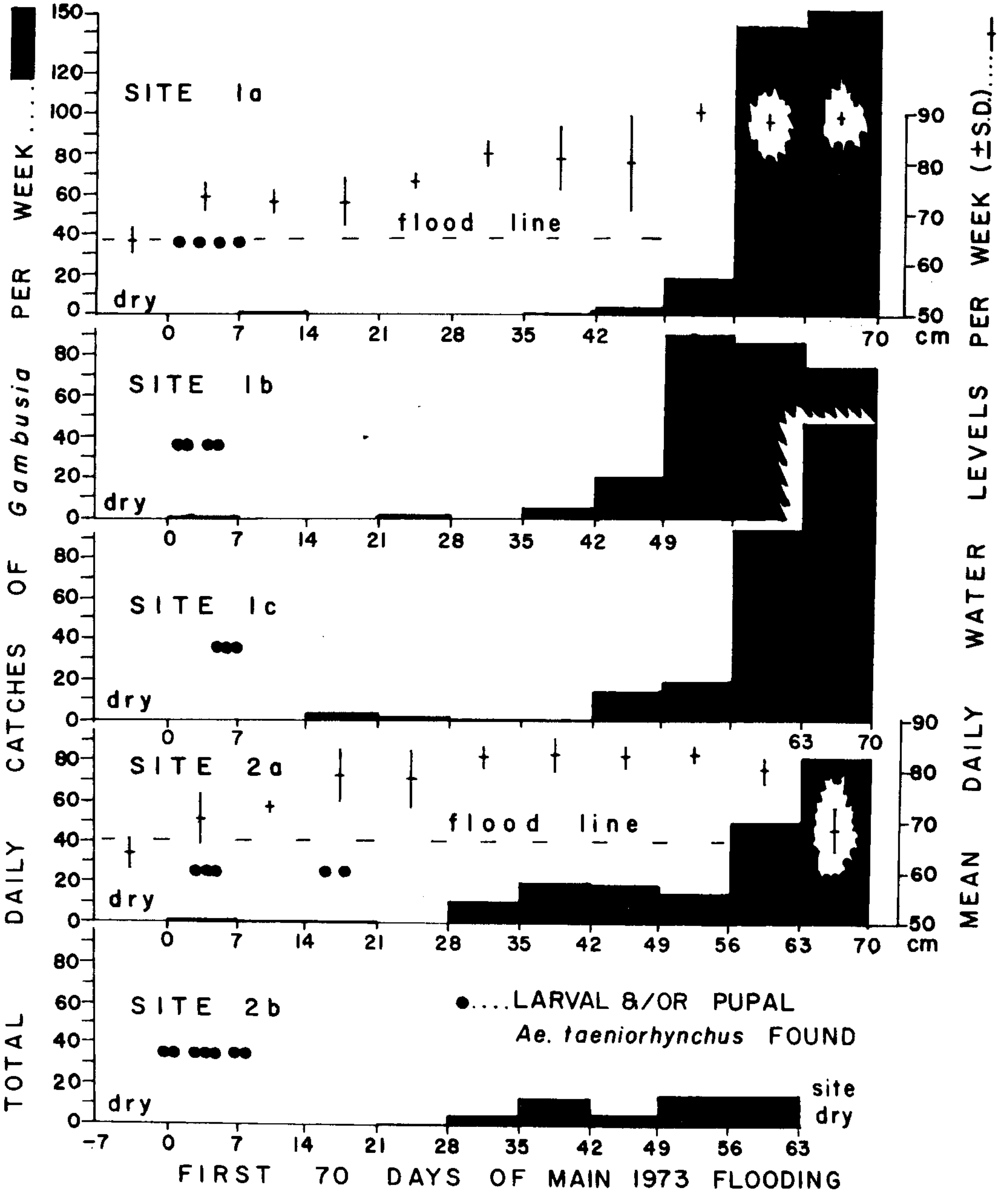

Fig. 2. *Gambusia puncticulata* catches, *Ae. taeniorhynchus* immatures occurrence and water levels at Salt Creek swamp during the first 70 days of flooding of the 1973 wet season.

cause of this delay at Salt Creek was presumably the time taken by *G. puncticulata* to either disperse from their dry season refuges or to meet, mate and reproduce. The former possibility was unlikely since *G. affinis* can swim 475–900 m in 24 hours along densely-vegetated canals (Armstrong 1977). The only dry season refuges for minnows at Salt Creek were its lagoonal fringe and one permanent pool. The lagoonal fringe was 62 m from the nearest trap site (3) and 968 m from the farthest (1a). The permanent pool lay 450 m from the nearest trap site (1a) and 1125 m from the farthest (3). *Gambusia puncticulata* was probably able to reach all parts of the swamp within 3 days, when it was completely flooded.

The interval between successive generations of *G. puncticulata* is 9–11 weeks in the Bahamas (Krumholz 1963), suggesting that the delay was due to the length of this minnow's reproductive cycle. This view was supported by a comparison of *G. puncticulata* catches from Salt Creek

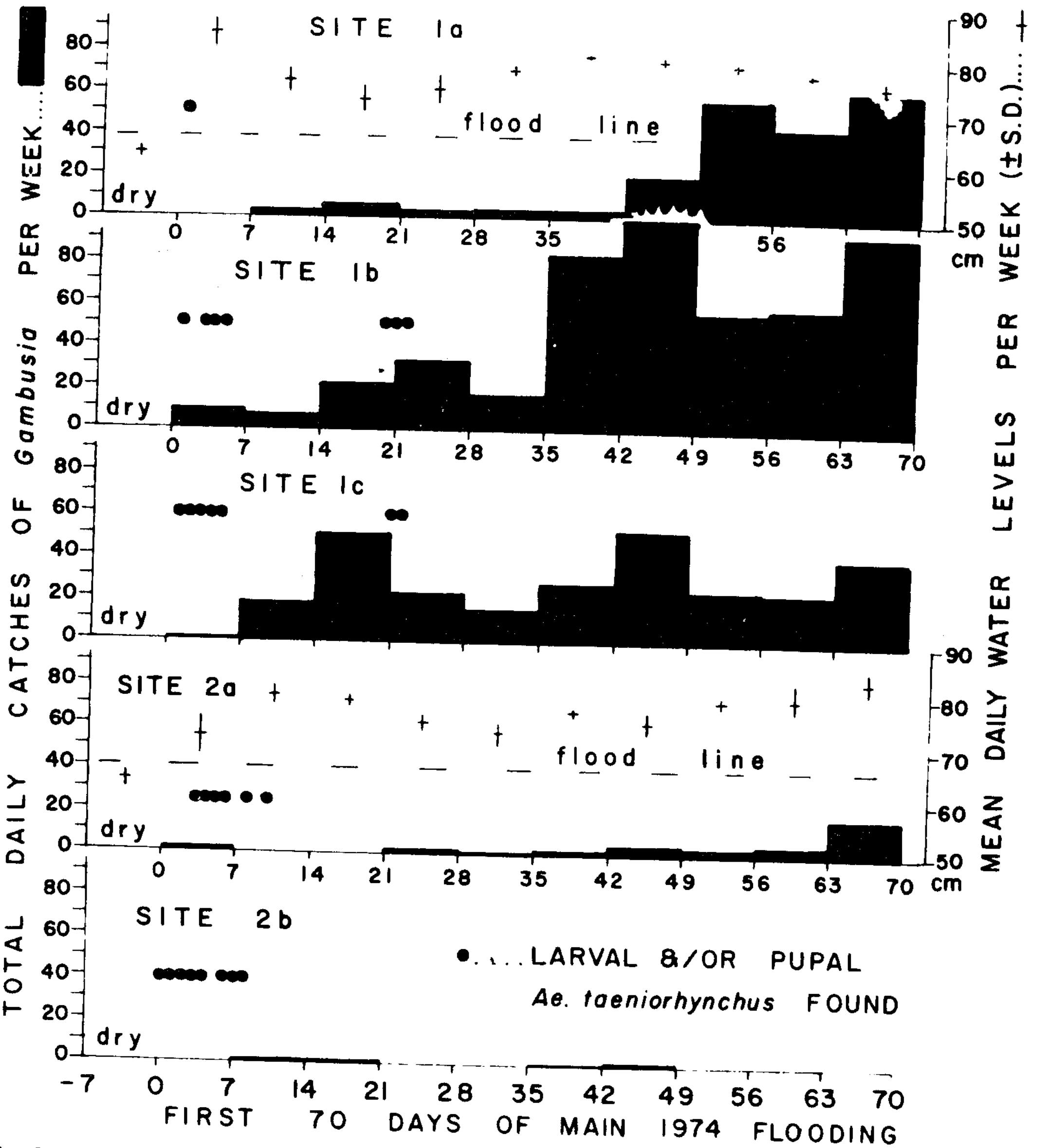

Fig. 3. *Gambusia puncticulata* catches, *Ae. taeniorhynchus* immatures occurrence and water levels at Salt Creek swamp during the first 70 days of flooding of the 1974 wet season.

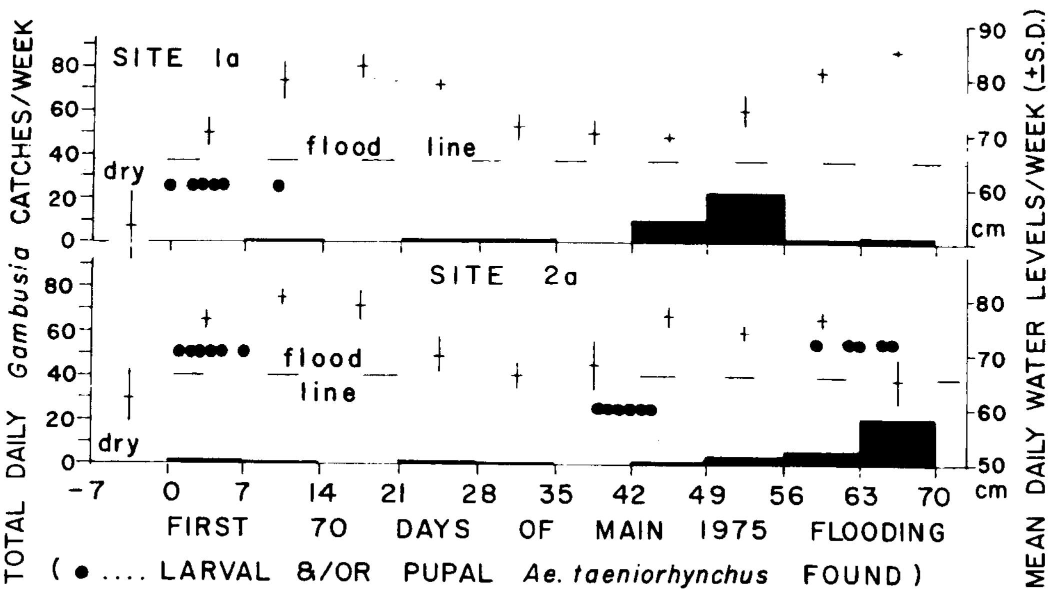

Fig. 4. *Gambusia puncticulata* catches, *Ae. taeniorhynchus* immatures occurrence and water levels at Salt Creek swamp during the first 70 days of flooding of the 1975 wet season.

swamp and from a permanent, freshwater pool during the 1973 and 1974 wet seasons. This pool had steep, limestone sides so that its area changed little, being ca. 39 m². Most fish caught in Salt Creek swamp were small and were either juveniles or non-gravid females, while sexually mature individuals were uncommon (Table 2). Fish captured in the permanent pool were mostly medium length and sexually mature. These differences suggested that the swamp population was a young growing one while that of the permanent pool was a mature, stable one. Flooding expanded the minnows' swamp habitat, allowing considerable increase in their numbers. This resulted in most of the *G. puncticulata* being small, juvenile fish. Since the pool's area varied far less, little change in minnow numbers occurred. Survival of young fish in this pool presumably depended largely upon mortality among older fish.

Very few *Cyprinodon v. variegatus* were caught in Salt Creek swamp, but they were seen in great numbers in extensive, permanent pools elsewhere on the island. Mosquitoes rarely bred in such pools.

ACKNOWLEDGMENTS

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Table 2. Composition of *Gambusia puncticulata* catches during the 1973 and 1974 wet seasons in 2 habitats on Grand Cayman.

Habitat	Body length (cm)			Sexual condition		
	<2.0	2.0–3.0	>3.0	Gravid ♀	Adult ♂	Other*
Mangrove swamp[1]	60.3%	37.6%	2.0%	3.8%	8.6%	87.6%
Permanent pool[2]	10.3%	74.4%	15.3%	56.4%	14.4%	29.2%

* Juveniles of both sexes and non-gravid adult females.
[1] Total of 8817 *Gambusia* caught at all Salt Creek traps.
[2] Total of 6161 *Gambusia* caught at one trap.

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