MOSQUITOFISH *GAMBUSIA AFFINIS HOLBROOKI* AS A MALARIA VECTOR CONTROL AGENT IN GEZIRA IRRIGATION CANALS OF THE SUDAN

ALI AHMED MAHMOUD

Department of Pathology, College of Medicine, King Saud University, Riyadh, Saudi Arabia

The poeciliid fish *Gambusia affinis* (Baird and Girard) has been recognized as predacious on mosquito larvae since the 19th century (Krumholz 1948). Today it is the most renowned and most widely introduced mosquitofish in the tropics and subtropics (Bay 1967). The subspecies *G. a. holbrooki* was introduced into the Sudan from Egypt in 1935 (Sudan Government records).[1] The fish has since been kept in small ponds, at Wad Medani, in Gezira Province, (central part of the Sudan) to supply mosquito control needs wherever they arise. In 1972, Nugud[2] used the fish in some irrigation canals in Gezira Irrigated Area (G.I.A.) in a small pilot project to control malaria vectors in canals where copper sulphate had continuously been used as a molluscicide. He found that the fish were not affected by the chemical at the concentration used.

This study assessed the feasibility of using *Gambusia* in the control of larvae of *Anopheles arabiensis* (Patton), the chief vector of malaria, in irrigation canals in G.I.A.

Trials were carried out in Gezira Irrigated Area in the Sudan. Medium size irrigation canals of about 1 m depth, 2 m width, and 4–10 km length, officially classified as minor canals, were selected as sites for the trials. Twenty such canals were seeded with *Gambusia* for two consecutive years while five others were used as control for monitoring density of mosquito larvae. The fish were collected by sieves from rearing ponds at Wad Medani, about 20–25 km from the trial sites. They were transported to the canals in 4-gallon tins half-filled with water. About 200 fish were placed in each tin. Fish were protected from direct sun by covering the tins and cushioning them against mechanical shocks.

During the first year the fish were released at the tails (terminal area) of the canals. About 1,000 fish were stocked at each spot by pouring directly from tin to canal. The second year fish were evenly distributed throughout the canals. In each of the 20 canals, fish were released and distributed at a number of locations at 1 km intervals (a total of 8,000–12,000 fish per canal depending on its length). This was carried out during the month of October.

Since *Gambusia* is a surface feeder (Hess and Tarzwell 1941, Wood 1976), this was used as a criterion to ascertain its presence or absence in any one area. Observations were carried out during the late morning hours (1000–1200 hr) at weekly intervals. The densities of *An. arabiensis* larvae in the canals were measured by dipping, prior to fish release. Dipping was carried out at two sites per kilometer in each canal at a rate of 10 dips per spot. This method was followed for assessment of larval densities in the canals every week throughout the second year of the trial. The total collection in 4 weeks was converted into 100 dips/canal/month. Fish densities were assessed at each spot where dipping was made at a unit water surface area and then calculated per m^2.

During the first year of the trial, *Gambusia* were traced at the tails (terminals) of some of the canals. Since the fish were not observed regularly and the numbers seen were relatively low, no specific data were recorded the first year. During the second year, however, the fish established very well in most of the treated canals within a period of about five months from the time of stocking. Schools of adults and young fish were observed at various sectors of the canals. The highest densities of fish were observed during the period from April to June (Table 1). These densities gradually diminished during the flood/rainy season (July–October) when the water in the canals became muddy and turbid. During this period the fish were seen mainly at the tails of the canals. However the densities of the fish were minimum during the first three months (October, November and December) of the trials.

As it is now generally accepted that *Gambusia* prefer to feed on late instar mosquito larvae (Wood 1967, Mahmoud)[3] the densities of the larvae are recorded according to age (Table 1).

Anopheles arabiensis is the major vector of malaria in the Sudan and especially in G.I.A. where the other vector *Anopheles funestus* Giles had been eliminated by the heavy spraying of agricultural pesticides (Sudan Government Records[4]).

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[1] Sudan Government. 1935. Correspondence recorded of Medical Entomology Unit. Wad Medani, The Sudan.

[2] Nugud, A. D. 1972. Report on biological control by *Gambusia affinis* in Gezira Irrigated Area. (Unpublished report).

[3] Mahmoud, A. A., 1978. Ecological life history of mosquitofish (*Gambusia*) and its use in mosquito control. (Unpublished report).

[4] Sudan Government, 1975. Records of malaria control project, Ministry of Health, Khartoum (Unpublished report).

Table 1. Average density of *Anopheles arabiensis* larvae in 20 irrigation canals treated with *Gambusia* and 5 control canals.*

Month	Average larval density/100 dips: Treated canals instars I & II	III	IV	Control canals IV	Average density *Gambusia* 10m²
January	169	34	25	42	12
February	239	42	30	48	30
March	167	30	24	153	40
April	381	176	93	153	45
May	6	7	1	7	50
June	0	0	0	4	50
July	4	3	1	27	36
August	29	9	2	20	29
September	35	2	2	38	21
October	133	45	25	34	1
November	329	86	124	125	2
December	126	77	98	119	2

* Chi-square was calculated for comparison of IV instar larval densities in treated and control canals. $\chi^2 = 109.85$, 11 d.p., $P<0.0001$.

Although *An. arabiensis* prefers to breed in small accumulations of water such as small pools formed by animal footprints, limited numbers of its larvae have routinely been collected from irrigation canals, especially where dense vegetation covers the edges of the canals.

The introduction of *Gambusia* in the canals of G.I.A. was triggered by the problem of resistance to insecticides that was exhibited by *An. arabiensis*. Antilarval measures, including biological control by mosquitofish had first (1973) been tried as an alternative, later on (1975), fish were adopted as supplementary measure to adulticiding (Sudan Government Records).

During the first year of this study, *G.a. holbrooki* were released at the tails of irrigation canals, on the assumption that they would ultimately distribute throughout the canals since the fish is an upstream swimmer (Mahmoud, unpublished data). But, contrary to our expectation, the fish remained adjacent to the sites of stocking. During the second year larger numbers of fish were stocked at regular intervals throughout the canals. This method proved to be fruitful, and the fish successfully propagated all over the canals during the dry season. This fact indicates that the failure met with during the first year was mainly due to the method of releasing fish at one limited area of each canal. The fish would have gradually spread over long distances away from the tails, if they had been allowed ample time. But because of the relatively short breeding season and ensuing muddy and swift flood water, fish propagation was limited. Another factor that might have limited propagation was the relatively small number of fish (1,000 fish) released in each canal.

In the second year the *Gambusia* were put in canals during October. During the first three months they were seen in limited numbers at sporadic sites. Fish densities started to increase in January. Populations reached a maximum, in March, in all treated canals and continued at this level through July (Table 1). Active breeding of the fish, during March-July, was indicated by groups of young *Gambusia* observed swimming at the water surface. The breeding of *G.a. holbrooki*, as well as other activities, are usually enhanced by a rise in temperature (Maglio and Rosen 1969, Martin 1975). In the present study the increase in density of the fish and appearance of its young broods was observed during the hot (100–110°F) months, March–July (Table 1). The highest densities of the fish were seen at the tails of the canals, where the water was clear, with a very slow flow and stable habitat for almost the entire year. The canal terminals are usually the least affected by the muddy flood water and thus their ecosystems are rich in hydrophytes such as ferns and algae plus many aquatic insects, crustaceans and other organisms. These can provide good food sources for fish populations (Hurlbert et al. 1972).

The period from April to June represents the dry/hot season in Gezira. During this period the water level in the canals is generally low and the flow is slow. The canals are the only available breeding sites for mosquitoes. This time is also the peak season for *Gambusia* densities in the canals (Table 1). Since no other control measure is usually carried out in the canals during this time of the year, the low densities of larvae at the tails of the canals (May–July) can be attributed to the action of *Gambusia*.

Although *Gambusia* is a good general predator of mosquito larvae, it has some limitations as a means of biological control. In a situation such as the irrigation canals of Gezira, there are some factors that limit its action. These factors include the seasonal fluctuations in the water conditions and the sequence changes in the ecosystem; and also the relatively short duration of conditions that favor the flourishing and propagation of the fish. In G.I.A. the flow of water from large to branch canals is controlled by gates that are opened at certain times; this system deprived the *Gambusia* from free movement into the smaller canals which are usually richer in mosquito larvae than the larger ones where the fish had originally been stocked. Moreover, during the rainy season, which is also the peak season for malaria transmission, there are uncountable rainwater pools that furnish *An. arabiensis* with adequate breeding sites which are usually more favorable than irrigation canals but less favorable for the fish survival.

All the above factors, and possibly others, negate *Gambusia* as an efficient mosquito control measure during the peak season of malaria transmission. However, the fish are found to be effective against mosquito larvae in the irrigation canals during the dry season when the canals are the main breeding sites for mosquitoes. During this time the canals are also most suitable for the breeding and propagation of *Gambusia*.

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OVIPOSITION BEHAVIOR OF *AEDES TRISERIATUS* AND *AEDES HENDERSONI* ON THE DELMARVA PENINSULA[1]

GARY G. CLARK[2] AND GEORGE B. CRAIG, JR.[3]

Aedes triseriatus (Say) and *Aedes hendersoni* Cockerell are sympatric species in eastern United States (Zavortink 1972). Intensive studies conducted on mosquito fauna and arboviruses of the Delmarva Peninsula by Saugstad et al. (1972) and LeDuc et al. (1975) revealed the presence of *Ae. triseriatus*, but did not detect *Ae. hendersoni*. The present study was undertaken to determine if the latter species occurs on the Peninsula and, if so, to describe its oviposition preference in relation to that of *Ae. triseriatus*.

One hundred and twenty ovitraps, prepared from aluminum cans painted black and containing balsa stick inserts (Novak and Peloquin 1981), were placed at ground level and at 3 and 6 m on trees in each of four 10-tree transects. Two transects were located in the Pocomoke Cypress Swamp (PCS), Worcester County, Maryland. The area and vegetation have been described in detail by Joseph and Bickley (1969) and Saugstad et al. (1972). These transects were established at the interface between the closed rootmat swamp and the upland hardwood forest, approximately 500 m apart. The more southerly transect was characterized by the nearby presence of discarded automobile tire casings that yielded *Ae. triseriatus* and *Ae. hendersoni* larvae. Two similar transects were established approximately 36 km east-southeast of the PCS in the Chincoteague National Wildlife Refuge (CNWR) at the southern end of Assateague Island, Accomack County, Virginia. This area was described in detail by Buescher et al. (1970). Transects at CNWR were located in deciduous woods, primarily *Quercus* spp., adjacent to freshwater swamps north and south of the island access road, approximately 0.5 km from the point where the access road enters the island. Traps were placed in the field on June 4,

[1] The views of the authors do not purport to reflect the positions of the Department of the Army or the Department of Defense.

[2] Department of Arboviral Entomology, Disease Assessment Division, U.S. Army Medical Research Institute of Infectious Diseases, Fort Detrick, Frederick, MD 21701.

[3] Department of Biology, University of Notre Dame, Notre Dame, IN 46556.