The use of fish for mosquito control is not a new concept. The technique was first seriously investigated in the early 1900's after it was discovered that malaria was transmitted by mosquitoes. Interest in larvivorous fish suffered with the advent fast-acting residual insecticdes. However, renewed attention is being given to fish as biological control. Two reasons for this change in attitude are the greater pesticide contamination on the environment and insecticides have costly, shorter-lasting evolution on resistant mosquitos.

Gambusia affinis has become almost synonymous with biological control of mosquitoes , mosquito fish offer great potential as an adjunct to chemicals for mosquito control.

HISTORY

First writings on Gambusia affinis in 1854. Early 1900's their usefulness mosquito predators become established. During that period, the first long distance transplantation of mosquito fish was made. At the request of the Hawaii Agriculture Experiment Station, about 150 Gambusia were brought from Seabrook, Texas to Honolulu in 1905. The fish flourished and by 1907 they had already established a record of being extremely effective mosquito predators. In 1921, Gambusia from Augusta, Georgia to Spain. Italy imported Gambusia from Spain in 1922 and ~~from Spain in 1922 and from~~ Italy distribution was soon extended to countries throughout Europe.

Gambusia affinis also received widespread distribution and use in malaria control. In the United States, (1921) reported that the use of mosquito fish during 1920 malaria control campaigns was responsible for producing more permanent results in many southern states at a reduced cost. During World War II, U.S. Army Malaria Control Units utilized Gambusia in the Pacific to control anopheline breeding in wells and cisterns. California (originally imported Gambusia from Texas in 1922) successful control of the important disease vectors, Culex tarsalis and Anopheles freeboni, was achieved with the use of mosquito fish. Because of its use for mosquito control, Gambusia affinis probably has the widest range of any fresh water fish. It is found in nearly all the warmer regions of the world and has been successfully established in areas where relatively severe cold weather occurs, such as Utah, Michigan, and Canada.

BIOLOGY

Gambusia affinis is one of some 150 species of fish in the family Poeciliidae. Members of this family are all from the New World with the majority found in Central America and the West Indies. The name Gambusia comes from "Gambusino", a provincial Cuban word which denotes "nothing". Thus, it is said, "to fish Gambusinos is to catch nothing". The species name, affinis, means "neighboring" or "related". Because of its well known appetite for mosquito larvae, the common name usually applied to the species is "mosquito fish". It also be referred to a a "top minnow". Due to its habit of seeking food at the surface.

* OVER Head Projector

A relatively flat head, small body and protrusible mouth are characteristic of mosquito fish. At birth, and for some time afterward, the anal fin of both sexes is similar. However, sexual dimorphism is later exhibited as the fin becomes small and rounded in the female while that of the male is modified into an elongated, rod-shaped copulatory organ, the gonopodium.

The gonopodium is normally carried backward and parallel to the body, but it can be quickly moved at any angle, forwards or sideways. Adult females range from 1 to 2-½ inches in length while the mature males average about 1-¼ inches. Female Gambusia attanin greater lengths than males since they continue to grow until death. Males, however, grow very little after the gonopodium is completely formed. In both sexes, the body is pale grey with a blue metallic sheen. The belly is silver and the back, or dorsum, is brown or olive green. In many cases, there is a dark, transverse bar across the eye.

[redacted] the U.S. ([redacted]) divides the Gambusia affinis between the two subspecies. The range of the eastern subspecies, G. affinis holbrooki, is given as Delaware to Florida and Alabama, Western subspecies, G. affinis affinis, Alabama to Illinois and south to the Texas coastal region. In Alabama, the two subspeices reportedly meet and their distinctive features are lost. It is likely that this ph[redacted]n occurs elsewhere in other states.

Gambusia affinis is found in all sluggish or standing lowland waters which are accessible to it through natural channels. It thrives in a wide variety of water types including fresh or brackish, clear or muddy, shallow or deep. Gambusia is seldom found in swift-flowing streams or water that is polluted with chemical wastes acid in nature, but it can tolerate water moderately polluted with sewage. When larger fish are not present, Gambusia may be found in deep water. However, it shows a distinct preference for shallow water where it is protected from predaceous fish and where food and vegetation are more abundant. Observed large numbers of mosquito fish in water less than 1 inch in depth.

Although essentially a warm water fish, Gambusia can tolerate a wide range of temperatures. Reported mosquito fish withstanding water temperatures of 107.6°F in nature. ~~Conversely~~, relatively cold water strains have been developed and have been reported to successfully overwinter under ice in certain areas. It should be noted that during winter, the fish hibernate in the lower water depths and are rarely seen until the spring when water temperatures become increasingly warmer.

It is well known that Gambusia can inhabit areas seriously deficient in dissolved oxygen for short periods of time without apparent stress. Specially, their dorsally oriented mouths and flattened heads enable them to effectively utilize the oxygen-rich water at the air-water interface without dramatically altering their usual swimming posture.

FEEDING BEHAVIOR

Gambusia feed on a number of aquatic organisms including mosquitoes. They are, in fact, voracious feeders that consume a wide variety of phytoplankton, zooplankton, as well as some of the larger aquatic insects. Insects constitute a large part of the diet, a majority of the Gambusia studied also consumed some plant tissue consisting mostly of algae. In determining what organisms will be taken as food by Gambusia it would appear that availability is more important than choice. Studies in Alabama demonstrated that when mosquito populations increased, the number eaten per fish, also increased. By analysis of stomach contents, it was also found that a peak in feeding activity occurred soon after daylight with a decline to a minimum in the later afternoon and then an increase to a second, but lesser peak, in the evening. Gambusia searches for food at or near the water surface, but will search the bottom if food is scarce elsewhere.

Mosquito fish are highly attracted by prey movement. Their range of vision to be only 4 to 5 inches, and the movement of larger prey is more quickly noticed than small prey. Anopheles larvae will, in fact, remain motionless when fish are nearby. Such a protective instinct is probably highly developed in mosquito larvae since "inactivity" is the only protection they have against their fish predators. The fact that Gambusia show increasing preference for later instars and even greater ? APETITE ~~[illegible]~~ for pupae, which ~~has~~ HAS been reported by a number of investigators.

Voracious appetite Gambusia have for mosquitoes has been reported on several occasions. One large female to eat 225 larvae and pupae within a 1 hour period. In another instance, a pair of half grown Gambusia consumed over 5,000 larvae in 11 weeks. All sizes and ages of Gambusia readily feed on mosquito larvae, and even fry only a few hours old will attack young instars. Gambusia are also cannibalistic and will prey on their own young if given the opportunity. POUR MOSQ INTO AQUA

REPRODUCTION

Gambusia (live bears), give birth to smaller numbers, but the newborn are in a more advanced stage of development and better adapted to begin the struggle for existence than most fish hatched from eggs.

After mating, a female Gambusia has the ability to store the sperm and deliver a number of successive broods without further contact with a male. Mating is strictly promiscuous and pairs are not formed as in many egg layers. The fertilized eggs hatch within the body cavity of the femal and the young lie folded with head and tail ~~meeting~~. They are delivered in this form at birth; either one or two at a time. Almost immediately, they straighten out and swim to the nearest refuge. At birth, they are approximately 3/8 inch in length, and the ratio of males to females is essentially 1:1. As the fish grow older, this ratio gradually favors the females since they are hardier and live longer than the males.

A gravid or sexually mature female is easily recognized by the distended abdomen and a large blacktriangle area in front of the anal fin known as the "gravid spot". Due to black pigment in the peritoneum (a thin membrane which lines the abdominal wall and various organs) ~~which~~ and shows through the distended abdominal wall of the pregnant female. The pigmented area is also found in immature females, but it reaches its maximum size just before the female gives birth.

Over Head Again

The average gestation period in Gambusia is 23 to 24 days. Time required for a single brood to be born, will take about 30 to 60 minutes. On the average, three to four broods will be produced and, depending on the size of the female, the number of fry per brood may av erage from 40 to 104, although broods of 300 or more may occasionally be encountered. The female will have broods throughout the summer at intervals of 3 to 6 weeks, the length of the breeding season varying with the latitude and climate. Breeding season begins in May and ends in September or October.

Mosquito fish may live for 4 to 5 years in aquaria, but they seldom survive more than 2 years in the wild. As a general rule, both males and females were found to die the same summer in which they reached maturity. However, the maximum life span was found in females which did not become mature until their second summer. These fish ~~liberated~~ Had their series of broods and died at an age of 15 months.

CAPTURE & TRANSPORTATION

Mosquitofish and other small fishes present some rather unique problems in their safe transport.

The quantity of fish that can be transported safely is basically dependent upon the condition of the fish, physical handling and water quality. If the fish aren't greatly stressed in their capture, loading and movement, ~~resultant~~ survival rates will usually be quite good. Conditions that produce stress are: rough handling in nets and seines; transfer of fish from the seine to the truck; temperature shocks; and enroute tank water sloushing. Other relevant factors which influence the capacity of any live-hauling system are as follows:

1) water volume capacity of the transport tank;

2) tank water temperature;

3) temperature of the water at the fish source;

4) ~~ambient~~ air temperatures encountered enroute;

5) condition, sex and size of the fish collected;

6) seining and other handling methods used;

7) dissolved oxygen content of the transport water ~~maintained enroute; inhanced by agitators, compressed air or compressed oxygen~~;

8) cleanliness of transport water maintained enroute; Advised NOT Feed Fish

9) total time or distance involved in transport;

10) functioning of the aeration system;

11) quality of roads driven; and

12) the time of year, ~~with respect to all environmental factors~~.

~~Slide looking for fish etc~~

With so many important elements involved, the best way to arrive at a safe hauling capacity is to thoroughly test each transport system by startting with a relatively small number of fish and slowly increase the load each trip until signs of stress or mortality are observed. Male mosquitofish will usually begin to suffer first, so by keeping a close watch on male mortality one is likely to gain some measure of induced stress. Generally speaking, most well-designed transportation systems will be capable of handling fish loads ranging from 0.5 to 1.1 lbs of fish per gallon (60 to 132 grams per liter) of transport water. For very short hauling distances, it may be possible to increase these figures somewhat; but one should do so with extreme care.

TANKS - Numerous types of containers can be used to transport mosquito fish and other small fishes. It is crucial that any tank used must be rigid enough to withstand the water pressures involved, be relatively nontoxic to fishes, and be watertight. Tank configuration is also important if one is to maximize hauling capacities. A tank should be obtained or built with as great a surface area to volume ratio as is practicable. ~~This factor aids in the exchange of gases at the air-water interface and thereby supplements aeration~~. In other words, a long, wide rectangular tank would be able to support more fish than would an oil drum of equal volume if supplemental aeration wasn't provided. Any tank used should be filled to near capacity to provide as much volume as possible and to minimize enroute sloshing or surgeing. Interior baffles may be inserted to reduce sloshing; but should be removable to facilitate fish access and emptying.

Transport tanks can be constructed of aluminum, steel, plywood, plastic or fiberglass. slide TRUCK & TANKS #2 off

STOCKING RATES FOR MOSQUITO CONTROL - There are probably as many different but appropriate stocking rates as there are types of mosquito sources. Exact stocking rate figures are impractical, if not impossible to itemize because a rate that works well in one particular mosquito source may be either too low or too high for an identical source in a different California locale. In addition, when one takes into account variations in weather conditions and other environmental factors, appropriate stocking rates may change for the same source from one year to the next.

Technicians must consider the species of mosquito they are intending to control with fish. Mosquitofish applied in one source that produces two species of mosquito may or may not provide the same level of control for both mosquito species. Therefore, it is usually necessary in such instances to stock for each mosquito species separately, even if this means one might be overstocking with regard to the other species present. Another factor that must be given thought is whether or not the stocking is for immediate larval control or for the eventual control of mosquito populations peaking later in the summer. Immediate control stocking rates are usually much higher than the rates required for eventual control. When stocking for eventual control, one generally assumes that the fish will reproduce in that source to the extent that ~~subsequent~~ production of fish will coincide with the production of mosquitoes, thus initial stocking rates can be significantly lower. When an attempt is made to coordinate the fish population in a source with a mosquito breeding period peaking later in the summer, one must give the fish an adequate lead time so enough fish are generated by that time to provide the desired control ~~efficacy.~~ It is therefore crucial that the fish be stocked early enough.

When stocking for perennial control in permanent bodies of water, enough fish must be applied to ensure survival and reporduction. Biologically speaking, it is possible to stock too few fish to guarantee survival of that population. Conversely, it is undesirable to overstock a source because this habitat may not be able to support that quantity of fish for an extended period of time. Stresses due to overcrowding of the fish will usually result in subsequent disease and mortality problems.

When stocking fish, water temperatures in the fish holding tank and the source to be stocked should ideally be the same. Thermal shock caused by rapid temperature changes can be lethal to fish; although mosquitofish show a remarkable ability to withstand temperature shocks that would kill other fish species. Stocking should never be done when the temperature of the source nears 100°F (38°C). Care must also be taken that no herbicides or other chemicals harmful to the fish are present in the source at the time of stocking.

<u>STOCKING</u>

In selecting a suitable stocking site, several factors should be considered. To begin with, the sites where Gambusia often fail include those areas which are too cold, too plant infested, too Large or too temporary for them to reach control levels ~~or where protection from natural enemies is not adequate~~. Slides #4

Areas in which mosquito fish generally provide adequate control include: ~~irrigation systems, drainage ditches~~, sloughs, ~~ponds, cisterns~~ STORM DRAINS, ~~shallow wells~~, watering troughs, ~~seepage areas~~, ~~borrow pits, sewage~~ oxidation ponds ~~or lagoons, water hazards on golf courses, undrained swimming pools, and other areas of standing water which allow for mosquito breeding~~. Gambusia are effective to ornamental fish pools, but are best used by themselves due to their aggressive behavior against other fish species such as goldfish. why is This? Slides #17 School Pools #1

While not normally required, artificial feeding may be desirable to achieve maximum potential in some areas. In such instances, the food of choice is "trout chow" such as fish hatcheries use. Slide #1 The amount of ~~trout chow~~ Fish Food necessary for good growth will be dependent upon water temperature, the availability of natural food, and the size and total numbers of fish to be accomodated.

After a site has been selected, approved, and properly prepared, Brush slide #3 the number of fish to be stocked will be governed by the ~~surface area of water and the amount of protection available to the mosquito population.~~ conditions discussed earlier ~~Overstocking is usually not a critical factor. Therefore, when fish are readily available, the higher the number stocked, the quicker the degree of control~~. Turn off slides

The amount of time required for a population to reach a level sufficient to provide effective control will depend on the number stocked initially. When minimum numbers are planted, a period of 30 to 60 days may be required before the population reaches an effective level. It is, therefore, advisable to stock as early in the season as possible such as in April or May. After stocking, the populations may reproduce at phenomenal rates, reported that within 30 days, 4,000 to 8,000 fish were obtained from rice fields initially stocked with 200 mature females. Estimated that a total of 1.5 million fish were removed over a 3 year period from one pond initally stocked with 2,000 Gambusia.

INTEGRATED CONTROL

The management of pest populations through the use of integrated control techniques has received increased attentiØn in the past few years. Read Book The term "integrated control" is usually defined as the use of chemical, biological, and physical control measures either in sequence or simultaneously against, a pest population. IN a mosquito fish program, the central theme consists of using chemcials, namely larvicides and herbicides to augment the biological control efforts of the fish; thereby assisting in the achievement of adequate mosquito control. The larvicides are applied early to control new mosquito broods, and then they may be discontinued or lessend when the fish multiply and become fully effective. Herbicides, on the other hand, serve to control dense vegetation where mosquitoes seek refuge from the predatory Gambusia.

Obviously, the choice of insecticide is critical since a selective material is required which will kill the mosquitoes but spare the fish population. BTI B-Sph

12 Read Labels

Aquatic plants with slightly submerged leaves or with a dense network of roots near the water surface offered the best protection to immature mosquitoes from fish. Algal mats were also considered to provide good refuge ~~when water found in portions of the mat was sufficient~~ to harbor mosquitoes. Anopheles larvae have been found in the thin film ofwater that covers partially submerged leaves. In such instances, they cannot be detected or reached by larvivorous fish.

Slides Heavy Veg #3

Whenever possible, it is recommended that the vegetation be removed mechanically. If, however, a herbicide is required then a number of factors (1) if the plants growing in the shallow edges or margins, or on the bank above the water line; (2) if the water is free-flowing as in a canal or static as in a pond; (3) if the vegetation is a grass or broadleaf and if it is submerged or immersed; (4) will herbicide will be compatible with the aquatic animal life; and (5) if the treated water will be used for drinking by livestock, wildlife or humans.

Rodeo Label

Lets go Fishing Slides #4

FIRST Know where going Fishing News #1

Equipment needed #1

Using Equipment #5 3/16" Mesh Nets & Seins

Big Fish

2

Next Page Effectiveness

~~Next Page~~ ~~Test~~

EFFECTIVENESS

The effectiveness of Gambusia as a mosquito predator has been well documented over a period of 80 years.

Gambusia is a hardy species and yet their effectiveness in any given situation will depend on: (1) the amount and type of vegetation and debris present; (2) the density of the fish population; and (3) the existence of natural enemies such as predaceous fish. In situations where dense vegetation or debris provide adequate protection for larvae and pupae, good control may not be obtained.

Because the effectiveness of Gambusia is obviously dependent on the three factors discussed above, it may be ncessary to disturb or change one or all of these to obtain adequate control. This is very evident when Gambusia and mosquito larvae are found living together in the same areas. Necessary to modify the environment of such an aquatic situation in order to magnify the effectiveness of Gambusia as a larval predator. This can be accomplished by removing the vegetation, increasing the number of fish by stocking, providing places of refuge, or eliminating natural fish predators.

In Michigan, experiments over two summers that Gambusia were about 81% and 95% e3ffective in controlling anophein breeding ponds. In Georgia ponds and swamps, found mosquito fish to be responsible for 50% and 80% average reduction in anopheline and culicine populations. The most effective control of both species was in artificial ponds while control was much less successful in several heavily vegetated swamps. Similar observations have been made by that absolute or 100% control cannot be expected in every situation. The fish may also be more effective under some circumstances than others. BUT They do play A MAJOR Role in Todays Mosquito PROGRAM

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