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CHIRONOMID CONTROL BY CARP AND GOLDFISH

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INTRODUCTION. This study on the use of carp, *Cyprinus carpio* Linnaeus, for the control of midges was undertaken as the result of observations on midge-carp relations at Lake Elsinore, California (Miller, 1951). There, in the year 1950, following a die-off of carp, enormous outbreaks of chironomid midges soon harassed local residents.

Although carp are omnivorous bottom feeders, their preference for chironomid larvae has often been observed. Thienemann (1954) reported that chironomids are purposely cultured in Asian rice fields for the production of carp. Sigler (1958) stated that chironomid larvae apparently constitute the chief food item of carp. Johnson and Munger (1930) found that carp were the heaviest consumers of *Chironomus plumosus* (Linnaeus) larvae in Lake Pepin, Minnesota. Assman (1960) found carp, roach, bream, and goldfish to have a decreasing order of effectiveness as predators on chironomid larvae.

The present study was conducted to determine the near and long-term value of carp and goldfish in chironomid control. The study was made at the Rio Hondo water spreading grounds of the Los Angeles County Flood Control District near Whittier, California, during the spring and summer of 1960. Water at these grounds is intermittently impounded for ground water replenishment. Due to the instability of the aquatic environment thus formed, enormous populations of chironomids are at times able to develop and create a nuisance before natural controls can become established. Anderson and Ingram (1960) were the first to study this problem and found carp to be more effective than brown bullheads, *Ictaluris natalis* (LeSueur), in reducing numbers of midge larvae.

MATERIALS AND METHODS. Tests 1 and 2 were made in 1/50-acre earthen basins excavated 4 feet deep in alluvial sand. Except for the checks, treatments were unreplicated because of insufficient basins. Tests 3 and 4 were made in earthen basins 1/80-acre by 2 feet deep, and all treatments were replicated 3 times.

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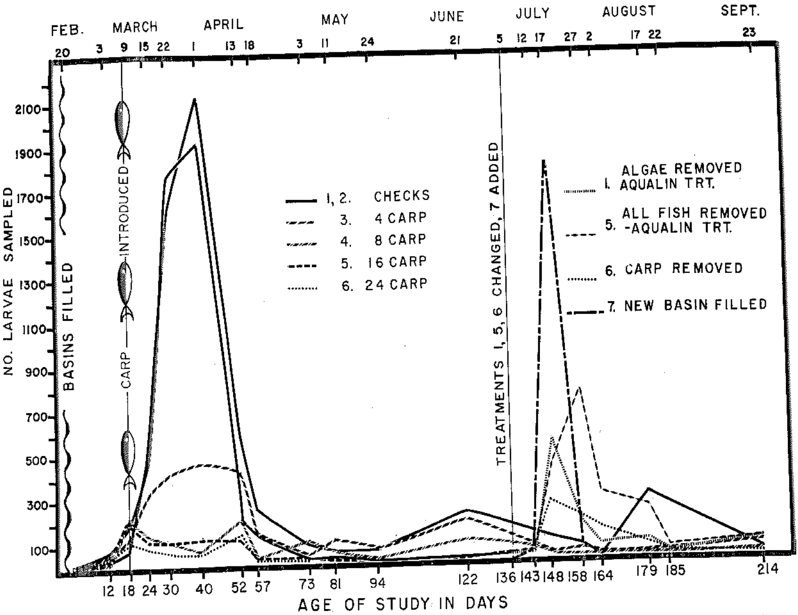

FIG. 1.—The effects of carp and pond maturation factors on chironomid larval populations. Treatments made in 1/50-acre basins wherein carp were stocked at rates of 150 (4 fish per basin), 500 (8), 900 (16), and 1,400 (24) pounds per acre. Aqualin[R]* treatments rid basins of incidental organisms including miscellaneous fish and algae which escaped mechanical removal. Larval counts represent totals for three subsamples (0.75 sq. ft.) for each basin.

* Registered trade name for acrolein algicide, Shell Chemical Company.

None of the basins contained outlets, but all were highly permeable. Basins were supplied with Colorado River water through short lengths of 8-inch pipe connecting them with a common canal. The mouth of each pipe was screened with ½-inch hardware cloth to separate fish in treatments from incidental species in the canal.

Basins were filled with water and sampled for larvae for several days before fish were introduced. Fish were weighed at the beginning and again at the end of the test. At the conclusion of Test 1, fish were removed from some basins by seining and electric shock, and from others by means of the chemical Aqualin®,[3] depending on the objective of Test 2.

Midge larvae, primarily *Chironomus californicus* Johannsen and *C. attenuatus* Walker, were sampled by dredging and combining three equally distributed 6-inch square scoops of substrate from each basin. Samples were then washed and screened (0.5 mm. mesh) for larval separation and counting.

EXPERIMENTS AND RESULTS. *Test 1.* In this test 4 densities of carp weighing between ¾ and 1¼ pounds apiece were compared for their relative effectiveness in chironomid larval control. The numbers of carp per basin used were 4, 8, 16, and 24, which converted to densities of 150, 500, 900, and 1,400 pounds of carp per acre. Two basins were left unstocked as checks.

Results—Test 1. From the time basins were filled with water (February 20, 1960) until carp were added (March 9, 1960), larval populations in all basins reached an average density of 153 larvae per sample (0.75 sq. ft.) (Fig. 1). Thereafter larval populations with carp at 500

[3] Trade name for an acrolein algicide manufactured by Shell Chemical Company.

pounds per acre or above dropped almost immediately while larvae in checks increased to a peak average of 2,000 larvae per sample within 3 weeks. Larvae with carp at 150 pounds per acre reached a peak of only 475 larvae per sample in the same period. Shortly after these peaks, larval populations in all treatments, including checks, behaved essentially the same. After this situation persisted more than 2 months, it was sought to determine why checks no longer produced more midge larvae than did carp treatments.

Observable changes which had appeared in the check basins but not in the carp treatments included dense growths of filamentous algae (*Cladophora* and *Hydrodictyon* species) (Fig. 2) and complex

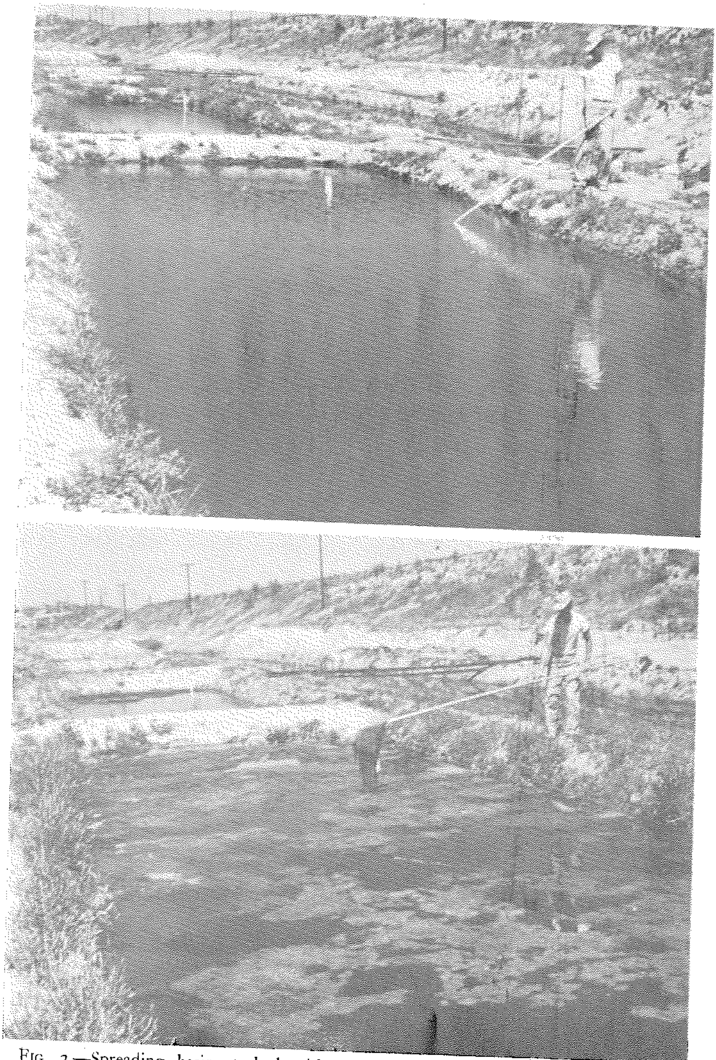

FIG. 2.—Spreading basin stocked with carp (top) is free of algae, while that at bottom, used as a check, is heavily infested with *Hydrodictyon* and *Cladophora* species. Both basins have contained water an equal length of time.

communities of invertebrates. Undetermined numbers of small fish (*Gambusia, Pimephales, Lepomis,* and *Carassius* species) had entered as fry through inlet screens and were developing in all basins. Also, another detectable change which affected all treatments was sediment. Sediment, by sealing the bottoms of basins, reduced the daily inflow of plankton and nutrient to basins and otherwise altered the larval environment.

Test 2. On July 5, 1960, in order to reveal what factors might be suppressing larval populations in checks and to evaluate the long-term value of carp in chironomid control, some treatments of Test 1 were removed. The algae, fish, and invertebrates which had developed in one of the checks were removed as best as possible by hand and what remained were destroyed by treatment with Aqualin at 9 p.p.m. After seining and weighing carp from Test 1, populations of 4 and 8 carp were immediately replaced in their original basins. These populations were then equal to 260 and 525 pounds of carp per acre, representing weight gains of 73 percent and 5 percent, respectively. The two larger carp populations were not replaced and one of the basins from which they were taken was treated with Aqualin to rid it of other biota.

Thus the biota in 3 of 6 basins (2 with carp and 1 with algae) remained unaltered, whereas other basins were variously rid of fish, algae, and invertebrates in an attempt to reveal their influence on larval chironomid populations. Meanwhile, a seventh basin was flooded to simulate the original unfouled condition of the older basins as of the preceding February.

Results—Test 2. Larval populations in unaltered environments remained nearly homeostatic, tending slightly to decline, while those in new treatments ascended sharply within 12 days after treatment. With the exception of treatment 7, the sharpest increases (44- to 45-fold) in larval populations occurred where either fish or algae were removed followed by Aqualin treatment. The least increase (14-fold) took place where only carp were removed. In treatment 7 with its new unsilted basin, larvae reached an average of 1,800 per sample, or more than 3 times the highest population resulting from other treatments. This population compared favorably with those obtained in similarly unsilted basins early in Test 1.

The sharper emergence peaks in July, compared with those of the preceding March, reflect the shorter development period (10–14 days versus 6–9 weeks) for Southern California midge species during the warmer season. Following these induced population peaks, larval densities in all basins quickly resumed pretreatment levels of homeostasis. Treatment 7 was discontinued shortly after July 27, when its basin was accidentally invaded by a large school of goldfish.

Test 3. Once the level of larval reduction was established for approximately 500 pounds of carp, numbering 400 fish per acre, other number-combinations were compared and goldfish were included as well. Two number-combinations of carp (4 and 8 per basin), equal to 340 pounds per acre, were compared with goldfish (52–75 per basin), equal to 160 pounds per acre. Each treatment was replicated 3 times.

Basins were filled with water on May 26, but not stocked with fish until July 22 because of intervening algicide studies (Jordan *et al.,* 1962). Ten days before Test 3 all basins were treated with Aqualin at 9 p.p.m. to eliminate remaining algae and miscellaneous organisms. After fish were stocked they were left undisturbed for 1 month and then were seined for weighing. Fish were weighed on August 24 and only those from the 8-carp basins were replaced. Larval sampling was then continued in all basins.

Results—Test 3. Both carp and goldfish populations weighed the same (5.6 pounds per basin) after the first month of the experiment (Table 1). This was despite the fact that one carp had died in one of the 4-carp basins. Although these treatments were now equivalent to 450 pounds of fish per acre, their midge

TABLE 1.—Control of midge larvae by carp and goldfish stocked at different number vs. weight densities, Whittier, California, 1960 *

Fish stocked July 22	Mean weight of total fish per replicate in lbs. July 22	Aug. 24	Means of larval populations July 27	Aug. 2	Aug. 9	Aug. 16	Aug. 24	Sept. 2	Sept. 8	Sept. 15	Sept. 22
8 carp	4.3	5.7	376	42	39	28	17	33	42	68	62
4 carp	4.2	5.6	296	62	42	20	22**	391	309	157	88
52–75 goldfish	2.0	5.6	388	65	89	53	23**	366	354	786	243
Check	..	..	205	110	69	5	15**	12	9	54	83
1 s.d. (0.05)	..	..	177	122	75	28	8	280	447	155	84

* Treatment means for three replicates (9 samples, 0.25 sq. ft. ea.).
** All fish weighed on August 24 and "**" removed.

control effectiveness was not apparent because of coincident larval reduction in check basins. As a matter of fact, during July and August, algae and other biota infested check basins so rapidly that during one period larvae in checks were significantly fewer than in goldfish treatments. Only by later eliminating fish treatments was it possible to demonstrate the larval control they had effected. When goldfish and populations of 4 carp per basin were removed, midge larvae increased more than 30-fold over checks within 1 week. These differences remained significant for 3 weeks.

Test 4. In Test 4, the transition from larval suppression by algae and associated organisms to control by carp was investigated. Populations of 3 and 4 carp removed from Test 3 on August 24 were placed in algae infested basins which had been filled with water since June 17. Larvae were at this time present at low concentrations, earlier shown to be characteristic of stabilized checks. The introduction of carp eliminated the algae, but larval populations remained the same.

DISCUSSION. Both carp and goldfish effectively prevented massive short-term chironomid midge emergence when they were stocked at above 150 pounds per acre in recently flooded water spreading basins used for ground water recharge. However, over the long term carp and goldfish lost much of their midge control advantage to other naturally occurring factors.

Ball and Hayne (1952) studied a lake from which fish had been removed by rotenone and concluded that other factors limited the invertebrate population to only twice that which had occurred in the presence of fish. In our studies we observed that filamentous algae can be one of these factors. In basins where algae were removed chironomid larval populations increased as much as in basins where carp were removed. Where Aqualin was then used to destroy algal remnants and miscellaneous organisms, larvae further increased, perhaps by obtaining additional food from the resulting organic breakdown.

Over the long term, pond siltation seemed to be more important than either algae or natural enemies in limiting larval chironomid development in test basins. Flood control records show that previously dry basins absorb from 4–10 feet of water per day, whereas basins which have been wetted for a week or more absorb less than 2 feet of water per day.

Consequently, new basins import proportionately more free swimming larvae and water-borne organic matter than do those which have become established. Detritus feeding midge larvae benefit accordingly and severe midge outbreaks occur before natural controls can take effect.

There are many chronic midge producing situations, however, in which pond siltation is not apt to be a serious limitation to chironomid development. Among these are sewage oxidation ponds, reservoirs with outflows, and eutrophic lakes. In some of these carp can be very valuable. One example is at Palm Springs, California, where carp have now provided us with satisfactory chironomid control in a 2.5-acre oxidation pond for more than 3 years. Unfortunately, carp are killed by conditions in many waste oxidation ponds.

Where carp can be used for midge control at chronic nuisance sites, their rate of stocking is of little importance. Due to their rapid growth rate and high fecundity, a few breeder carp placed in most suitable environments should produce control densities within 1 or 2 spawning seasons. Densities of 400–500 pounds of carp per acre which we found to be most effective in midge control are commonly encountered in nature (Sigler, 1958; Robel, 1962).

The degree to which carp can prevent midge nuisance is largely dependent on the area of midge production involved. A few midges per square foot spared by carp may go unnoticed emerging from a pond, but the same emergence accumulated over the surface of a large lake can pose a serious nuisance at strategic shore points. The senior author is personally familiar with such conditions as they occur at Chautauqua Lake, New York, and Lake Winnebago, Wisconsin, where carp and other larvivorous fishes are numerous.

In conclusion, carp and goldfish are capable and efficient predators of chironomid larvae and in limited situations they can satisfactorily control chronic midge outbreaks. Their control efficiency, however, is usually inversely proportional to the area of midge production. Where midge outbreaks are acute and attributable to recent changes in environment, carp are of less value. In these situations it is recommended that initial midge outbreaks be endured long enough to allow the midge producing environment to readjust to whatever change has occurred. Midge populations should then return to non-nuisance levels.

SUMMARY. Carp *Cyprinus carpio* Linnaeus, and goldfish, *Carassius auratus* (Linnaeus), were studied for their ability to control chironomid midge larvae (*Chironomus* sp.). Regardless of their numbers, both carp and goldfish effectively reduced midge populations when stocked at rates of 150–500 pounds of fish per acre.

The use of carp and goldfish for midge control in water spreading basins was discovered to be of only short-term advantage. Over the long term other factors, including pond siltation, filamentous algae, and natural enemies tended to maintain larval populations at the same level as did carp. Carp or goldfish introduced to basins following the establishment of larval control by other factors essentially replaced, rather than augmented, these factors. When carp or goldfish were removed from basins, larval populations increased only temporarily until other controls interceded.

It was concluded that carp are less valuable for midge control in large lakes and temporarily disrupted habitats than in smaller sources of chronic midge nuisance.

ACKNOWLEDGMENTS. The authors express their sincere appreciation to the following: The Los Angeles County Flood Control District, at whose Rio Hondo water spreading grounds the work was performed, for their generous support and assistance; Mr. A. A. Ingram, investigations engineer, for his technical assistance and enthusiastic cooperation; and Mr. H. Nakakihara, technician in entomology, for his assistance in sampling and evaluating these experiments.

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LABORATORY TESTS OF LARVICIDES FOR MOSQUITO CONTROL IN POTABLE WATERS[1]

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Activation of an *Aedes aegypti* eradication program by the U. S. Public Health Service (Schliessmann, 1964) has intensified the search for a mosquito larvicide treatment for potable waters. In Puerto Rico and the U. S. Virgin Islands, as well as other Caribbean areas, *Ae. aegypti* frequently is found breeding in the systems and artificial containers used for collection and storage of water for drinking or other domestic purposes in and around human habitations. Mosquito control in these situations is further complicated by the resistance of *Ae. aegypti* to DDT and/or dieldrin in much of the Caribbean area (Flynn *et al.,* 1964).

Zwick (1964) reported on the evaluation of DDT, dieldrin, fenthion, malathion, and carbaryl in various breeding containers common in the Caribbean area; while Schoof and Jakob (1964) presented laboratory data on the residual effectiveness of Bayer 37342,[2] SD-8447, and dimethrin against susceptible and DDT-resistant larvae. Mulla (1963) discussed the factors that may be responsible for the disappearance or ineffectiveness of compounds in water. The present paper gives results of laboratory tests of the residual larvicide activity of 11 compounds against *Ae. aegypti.* Data are also given for selected compounds against DDT-dieldrin resistant *Culex pipiens quinquefasciatus.*

METHODS. The toxicant in 1 ml. of ethanol (95 percent) solution was mixed with 225 ml. of tap water (pH—approxi-

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[2] The use of trade names is for identification purposes only and does not constitute endorsement by the U. S. Department of Health, Education, and Welfare.