Brown, Singh, and Castle (1964) in evaluating the Oregon salmon and steelhead sport fishery defined net economic value as "the estimated value of the sport fishery resource to a single owner who could charge for the opportunity of fishing." They further discuss methods of arriving at a value based on proposals of Clawson (1959), which employs a demand curve measured by plotting estimated costs per unit as a function of the number of visits per 1,000 population in a zone in a given distance range. As distance and travel cost increase, alternative fishing sites are selected more frequently. The authors believe that an important consideration is omitted from this method in that it does not consider benefits received by businesses engaged in furnishing fishermen with necessary items needed for participation in their sport. The results of this study show that for every dollar taken in by Auburn University, 1.7 dollars were spent in the surrounding areas.

Because this is a case study of Auburn University Fisheries Research Unit experimental ponds, results may not be comparable to privately owned ponds. The idea of fishing in experiment ponds may have attracted many anglers who believed that fishing would be better than in less intensively managed waters.

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THE EFFECT OF ROTENONE ON CERTAIN FISH FOOD ORGANISMS

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ABSTRACT

While all four fish food organisms (damselfly nymphs, dragonfly nymphs, mayfly nymphs, and caddisfly larvae) were killed by various rotenone concentrations, dragonfly nymphs had the greatest resistance and caddisfly larvae the least. Concentrations of rotenone currently being used in fish eradication would not effect the populations of the test organisms except that a very slight reduction in the caddisfly larvae population might result from the higher concentrations that are sometimes used. No change in structure or deterioration of gills before and after rotenoning could be observed by microscopic examination. Survival of all four organisms was excellent under laboratory conditions. Oxygen deficiencies were not a factor in killing test organisms. Mayfly nymphs consumed the greatest amount of oxygen and damselfly nymphs the least. The damselfly nymphs could survive a low oxygen tension without their gills while the other test organisms could not.

INTRODUCTION

The data herein presented concern the effect of rotenone on four immature gill breathing aquatic insects which are important fish food organisms.

Since rotenone is used extensively by all state conservation departments in both powdered and emulsifiable forms in fish population and aging studies, as well as in eradicating undesirable fish species, it was desired to learn what effect the concentrations of rotenone currently being used had on four fish food organisms. The study was started in September 1965 and concluded in June 1966.

Rotenone has been used by the South American aborigines as a fish poison. It is derived from the root of derris or cubé. It has many advantages as a fish toxicant because of its low mammalian toxicity and rapid detoxification in comparison to the chlorinated hydrocarbon and organic phosphorus insecticides which kill fish in high dilutions, but have high mammalian toxicity and a long residual action (Leonard, 1939; Smith, 1939; Greenback, 1940; Ball, 1945; Krumholz, 1948; Henderson, 1959).

Clemens and Martin (1953) recommended a concentration of between 1-2 ppm as a minimum for five percent emulsifiable rotenone (0.05-0.1 ppm rotenone) and slightly higher for powdered. Bennett (1962) found that it is risky to depend upon a five percent rotenone formulation of less than 1 ppm (0.05 ppm rotenone) to give a complete kill of fish. Leonard (1939) reported that a 0.5 ppm concentration of five percent derris root (0.025 ppm rotenone) was adequate to kill many common species of small fish. Krumholz (1948) used five percent rotenone concentrations of 1.0-1.5 ppm (0.05-0.075 ppm rotenone) which failed to produce a complete kill of bullheads. Burdick et al. (1955) indicated that 0.5 ppm of a five percent rotenone emulsion (0.025 ppm rotenone) was not adequate if a complete kill was required. Zillox and Pfeiffer (1956) found that Noxfish at a concentration of 0.5 ppm (0.025 ppm rotenone) was capable of killing all species. Burdick et al. (1956) showed that yellow perch were killed at concentrations of a five percent rotenone emulsion as low as 0.05 ppm (0.0025 ppm rotenone).

Reynolds and Barry (1951), Burdick et al. (1955), Leonard (1939), Zillox and Pfeiffer (1956), and Jenkins (1956) found that there are several factors that influence the concentration of rotenone necessary to bring about a fish kill. These include the size and species of fish, the temperature, pH, and turbidity of the water and the occurrence of weed beds.

While some studies concerned with the effect of rotenone on fish food organisms have been conducted, more laboratory and field studies are needed. Kiser (1962) showed that concentrations of 0.5 and 1.0 ppm of five percent rotenone (0.025 and 0.05 ppm rotenone) affected zooplankton but did not permanently eliminate it. Almquist (1959), working with the effect of five percent rotenone emulsions on fish food organisms in three lakes in Sweden, concluded that most of the zooplankton, much of the epiphytic and bottom animals and some of the phytoplankters were totally killed by 0.5-0.6 ppm (0.025-0.03 ppm rotenone) the concentration generally used in fish eradication.

The mechanism by which rotenone kills gill-breathing aquatic insects established. Hamilton (1941) concluded that death is caused by the constriction of the gill capillaries preventing the passage of blood through the gills. Danneel (1933) reported that the action of rotenone destroys gill tissue. Burdick et al. (1955) found, through the examination of gills of fish exposed to various concentrations of rotenone, no apparent mechanical injury or loss of filaments.

The mechanism by which rotenone kills gill breathing aquatic insects has not been established. Fukami (1962), working with the American cockroach, demonstrated that rotenone affected the conduction of the nervous system, but primarily caused a disruption of respiratory metabolism in the citric acid cycle. It is highly possible that this is the mechanism by which both fish and aquatic gill-breathing insects are killed.

MATERIALS AND METHODS

The test organisms used were the immature forms of the genera *Anax* (dragonfly nymph), *Agrion* (damselfly nymph), *Siphlonurus* (mayfly nymph), and *Phryganea* (caddisfly larva). These were selected on the bases of: (1) their importance in the diet of fish, (2) their ability to survive under laboratory conditions, and (3) their availability in great numbers to the investigators.

These organisms and all of the water used in all tests were collected from a sluggish portion of Sandy Creek, Hamlin, New York, which has an abundance of vegetation. The organisms were collected by dip and scraper nets and the water in five-gallon milk cans which were transported a short distance to an air conditioned animal suite at the State University College at Brockport, New York where all of the tests were conducted. The cases were removed from the caddisfly larvae with forceps. The water and organisms were acclimated to the controlled environment.

The purest form of rotenone possible according to the Pesticide Reference Standards of the Entomological Society of America and supplied by the City Chemical Corp. was used. It consisted of a minimum of 95.0% rotenone and a maximum of 5.0% related and inert compounds. It is insoluble in water. This was used because the writers were concerned with the effect of rotenone and not with the additives in the powdered form or additives and solvents used in commercial emulsions.

A five percent rotenone stock solution was obtained by adding five g of 95% rotenone to 90 g of water which was stirred to get the rotenone evenly suspended. A new stock solution was made for each test. By serial dilution a measured quantity was placed in glass battery jars each containing two liters of water to give the necessary rotenone concentration. Stirrers were used to keep the rotenone evenly suspended.

For each test organism duplicate concentrations required to bring about mortalities ranging from 100%-0% were used in approximately 10% intervals. Ten organisms were placed in each concentration and 10 in a battery jar with just water from the natural habitat. As dead organisms were found, they were removed from the battery jars. At the end of 48 hours the percentage of mortality was checked for each test organism at each concentration used. Four tests were run for each test organism and were averaged to give the percentage of mortality for each concentration that was used.

Exploratory tests were made on each test organism prior to full scale testing to learn the minimum concentration required to bring about 100% mortality and the maximum concentration at which 0% mortality occurred. This was done by decreasing the concentration in steps of 0.1 ppm concentration of rotenone.

The water occupied by the control insects was tested for dissolved oxygen, pH, temperature, and turbidity before and after each test and the results were averaged for the four tests. The dissolved oxygen in ppm was determined by the Winkler Method (Welch 1948, Limnological Methods), the pH was taken by a Beckman Expandomatic pH meter, and the turbidity was measured with a Jackson Turbidimeter (Welch 1948, Limnological Methods).

The significance of the gills in respiration was investigated by microscopic examination of the gills of each of the test organisms. Gills were examined from 10 of each of the test organisms that had not been exposed to rotenone and from 10 that had succumbed at the end of 48 hours to a rotenone concentration that produced approximately a 50% mortality. The second way in which this was investigated was by ligating the gills of the test organisms with white surgical linen thread. Ten ligated and 10 non-ligated test organisms of each genus were placed in separate battery jars containing two liters of water with a dissolved oxygen content of four ppm. Mortalities were checked at the end of a 24-hour period. The water with a low dissolved oxygen content was obtained by boiling water from the natural habitat and then letting it cool to room temperature.

RESULTS AND DISCUSSION

It was found that each of the four immature aquatic gill-breathing insects had a different range of rotenone concentrations in which mortalities from 100%-0% occurred.

The survival of all four organisms was excellent under laboratory conditions. The nymphs and larvae were classed as killed by the toxicant if they appeared near death and displayed only periodic twitching movements of legs and gills. Those which maintained coordinated movements of legs and gills at the time of observation were considered living. Figure 1 shows the concentration of rotenone in ppm and the average percentage of mortality for each test organism over a period of 48 hours.

Dragonfly nymphs showed the highest resistance to rotenone and the caddisfly larvae the least.

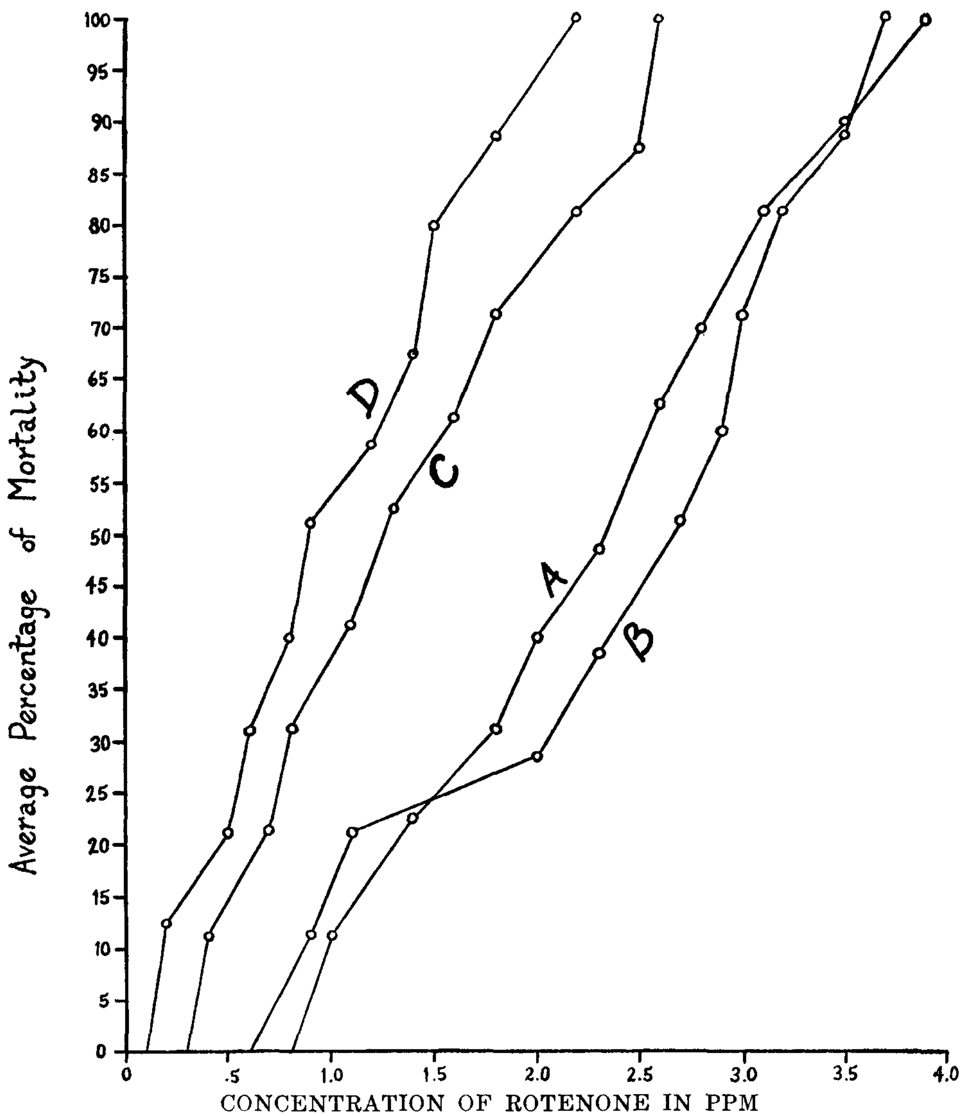

FIGURE 1. The concentration of rotenone in ppm and the average percentage of mortality over a 48-hour period for the four test organisms: A — *Anax* Nymphs, B — *Agrion* nymphs, C — *Siphlonurus* nymphs, D — *Phryganea* larvae.

Many biologists have criticized the use of rotenone in fish management because of the decimation of fish food organisms. This was contrary to the findings of the writers in regard to four important fish food organisms. It would seem that rotenone concentrations currently used by workers in fish eradication, thinning, population and aging studies, would not affect the populations of dragonfly nymphs, damselfly nymphs, mayfly nymphs, and caddisfly larvae. It is possible that a very slight reduction of the caddisfly larvae population might result where high rotenone concentrations were used, especially in weed beds, since 12.50% of these organisms were killed at a rotenone concentration of 0.2 ppm. However, it should be pointed out that some investigators have found that phytoplankton and zooplankton, which are basic to the productivity of any body of water, could be affected to some extent by rotenone concentrations now being used.

Table 1 shows the averages for the four tests for temperature, dissolved oxygen, pH, and turbidity of the water in the control for each of the four test organisms before and after the 48-hour test period. Mayfly nymphs consumed the greatest amount of oxygen and the damselfly nymphs the least. The turbidity both before and after all tests was <25 ppm. The pH of the water before all tests was slightly alkaline and at the conclusion was less alkaline or neutral. The range in temperatures never exceeded 3°F. Since there was no mortality of untreated insects in any of the tests, there was no indication that oxygen deficiencies were a factor in producing mortality of treated insects.

TABLE 1. The average of the four tests for temperature, dissolved oxygen, pH, and turbidity of the water in the controls for each of the four test organisms before and after the 48-hour test period.

	Water temperature		Dissolved oxygen (ppm)		pH		Turbidity (ppm)	
	Before	After	Before	After	Before	After	Before	After
Anax	70	72	10.2	8.3	7.2	7.0	<25	<25
Agrion	70	73	10.0	8.5	7.2	7.1	<25	<25
Siphlonurus	71	73	10.6	7.8	7.3	7.0	<25	<25
Phryganea	70	72	10.8	8.6	7.2	7.1	<25	<25

No structural differences or deterioriation of the gills could be observed by microscopic examination of untreated tests organisms and those that had succumbed to rotenone.

Table 2 shows the percentage of mortality for each of the test organisms under a low oxygen tension of four ppm over a 24-hour period.

TABLE 2. The effect of a low oxygen tension of four ppm on the four test organisms over a 24-hour period.

	Percent of mortality ligated gills	Percent of mortality non-ligated gills
Anax	100	0
Agrion	0	0
Siphlonurus	100	20
Phryganea	100	10

It would seem that dragonfly nymphs, mayfly nymphs, and caddisfly larvae needed their gills for survival under low oxygen tension while the gills of damselfly nymphs were not necessary.

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THE FOOD HABITS OF CHANNEL CATFISH IN SOUTH FLORIDA

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ABSTRACT

Since channel catfish, *Ictalurus punctatus*, were being considered as a possible predator for the control of forage fish in Florida lakes, a study of their food habits was conducted. An examination was made of the stomachs of 195 channel catfish collected in Lake Okeechobee, Lake Blue Cypress, and Lake Agnes, with trammel nets. The size range of fish examined was eight to 30 inches in total length. The