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NOTES ON THE USE OF DERRIS AS A FISH POISON*

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(Abstract)

Fisheries workers are finding that powdered derris root is a valuable aid in eliminating undesirable fish populations. The history of this substance is reviewed briefly, mention being made of its early use as a fish poison, as an ingredient of arrow poisons, and its development as an insecticide. Recent papers dealing with its physiological effect on fishes are mentioned.

In a series of laboratory experiments it was found that certain species of fresh water fishes are much more readily killed by derris than are others. The action proved to be somewhat faster in acid than in alkaline waters. Toxicity in an experimental aquarium dropped below the lethal point for fish between 20 and 30 hours after addition of poison, but a stock suspension of 1:100 concentration was little reduced in toxicity after standing in a darkened closet for 34 days. An increase in water temperature from 60 to 74°F. almost halved the time of death. A considerable deterioration in strength of the commercial powdered derris exposed to air and subdued light over a period of six months was detected.

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It was found that a concentration of one part powdered derris root (warranted rotenone content 5 per cent) to two million parts of water was sufficient to kill all species of fish tested. Furthermore, no fish was able to survive after losing equilibrium, even though transferred to pure, aerated water.

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In view of the increased interest being expressed in the use of derris as a fish poison, and because reliable information concerning the concentrations in which it becomes lethal is lacking, a series of laboratory experiments were conducted in the hope of acquiring some of the data requisite to a better understanding of its use.

Fisheries managers sometimes find it expedient to remove an entire fish population from a body of water. Such procedure may be indicated by a need for elimination of stunted populations or coarse fish to make room for more desirable species; as a means of removing infectious disease; or to aid in studies on the relation of natural fish supplies to the inherent productive capacity of a water. Complete elimination of a fish fauna by means of nets is practically impossible; dynamite is expensive and uncertain in efficiency; and copper sulphate usually destroys fish food organisms and plants as well as fish. Derris, on the other hand, appears to be highly efficient; its cost is reasonable; and there is every indication that plants and fish food organisms are not harmed by concentrations adequate to kill fish.

The purpose of this report is to place on record results of certain experiments directed at discovering the minimum lethal dosage of derris required to kill various species of fish of different sizes, at different

temperatures, and in waters of different chemical composition.

Rotenone ($C_{23}H_{22}O_6$), the most toxic principle found in the roots of various Leguminosae, was first obtained in crystalline form by the Japanese chemist Nagai (1902). It has been derived from a number of different plants, but commercial supplies, marketed under the name of "derris," are prepared chiefly from species of the genus Deguelia (= Derris), especially the oriental D. elliptica. Associated with it are deguelin, tephrosin, and toxicarol, none of whose virulence equals that of rotenone.

It is probable that primitive peoples have used derris as a fish poison since prehistoric times. Among the earlier accounts, in which the root is usually referred to as "tuba," or "akar-tuba," is that of Marsden (1811), who stated that natives of Sumatra employed juice from the pounded root to stun and kill marine fish left stranded by the tide in coral ledge pools. Hose and McDougall (1912) describe the ceremonies attending a "tuba" fishing party conducted by dyaks of Sarawak, and show that they have developed a number of legends and superstitions connected with its use. Newbold (1839) and others have mentioned the use of tuba, or derris root, in combination with other vegetable alkaloids, as an ingredient of arrow poisons prepared by Malaysian tribes.

Although relatively few publications deal with derris in its original role of fish poison, there is a most voluminous literature bearing on other aspects. Oxley (1848) reported that derris could be employed as an insecticide. Experiments on this phase continued, increasing greatly during the past fifteen years. Roark (1932) gives abstracts of 456 separate publications, appearing between 1747 and 1931, all of which concern derris. Some of these are taxonomic in character, but the majority report on chemical analyses and insecticidal uses.

At the present time the manufacture of insecticides absorbs almost all of the commercial derris output.

Investigators are generally agreed that while large doses of rotenone may prove fatal to man (Campbell, 1916, cites a case of suicide in Singapore by eating derris root), lethal dosages are not to be acquired by eating fruit sprayed with it. Haag (1931) swallowed an amount equal to 2.3 grains without experiencing harmful effects. Workers handling the material in its finely pulverized commercial form often notice severe nose and throat irritations. On several occasions I have experienced a sharp headache appearing from ten to fifteen minutes after first feeling respiratory irritation from powder inhalation. All of these symptoms can be avoided by protecting the nose with a folded cloth. Birdsall (1933) remarks that irritation from dust during the process of grinding the root is frequent, but states that no permanent ill effects developed in the case of a worker exposed to it over a period of two years.

It is apparent that in the case of fish the toxic effect of rotenone is exerted chiefly upon the respiratory system. Daneel (1933) tested the physiological action on various fishes, especially the crucian carp, Carassius vulgaris. He employed pure rotenone crystals, dissolving them in acetone before preparing his aqueous test solutions. By comparing the oxygen consumption of fish in a 1:100,000 rotenone solution with that of the controls, he found that within ten minutes the oxygen consumption dropped to 3 per cent of the normal as the rotenone took effect. Histological examination of the gill filaments of fish killed in this way demonstrated a withering and breaking-down of the gill epithelium, which obviously destroyed its respiratory function. Scheuring and Heuschmann (1935) tested the toxicity of various concentrations of

powdered derris root on trout, minnows, and perch, as well as on a variety of aquatic insects, snails, and crustaceans. Their results confirm the findings of Daneel (loc. cit.) as regards the corrosive and histolytic action of rotenone on gill epithelium. They found little ground for considering it very toxic to fish as a stomach poison. The utility of their numerous and well-conducted experiments is limited by the fact that the rotenone content of their powdered derris root was not certainly known. Roark (1931) has noted that the rotenone content of derris root may vary from 0 to 5.5 per cent, while the total ether extract of the root, including such toxic substances as deguelin, tephrosin, and toxicarol, may vary from 5 to 23 per cent. Consequently, it is difficult to apply Scheuring and Heuschmann's dosages to the commercial powdered derris root of the United States, whose rotenone content is standardized at 5 per cent.

Gersdorff (1930 et seq.) has published a series of reports dealing with the toxicity of rotenone and its associated toxic compounds and chemical derivatives, using the goldfish (Carassius auratus) as the test animal.

Experiments Conducted.--The following species of fish were used in these experiments: bluegill (Lepomis macrochira), common sunfish (Lepomis gibbosus), common sucker (Catostomus c. commersonnii), golden shiner (Notemigonus c. crysoleucas), common shiner (Notropis cornutus frontalis), mud minnow (Umbra limi), and goldfish (Carassius auratus). Invertebrate food organisms tested included damselfly nymphs (Argia sp.), stonefly nymphs (Acroneuria sp.), adult aquatic Hemiptera (corixids, and water bugs Belostoma sp.), caddisfly larvae (Limnephilidae), cranefly larvae (Tipula sp.), crayfish (Cambarus propinquus), scuds (Hyalella knickerbockerii), and snails (Physa sp.).

Experiments were conducted in waters of known chemical composition, derived from three sources--a spring supplying the Drayton Plains State Fish Hatchery, tap water from the Ann Arbor water supply, and acid water from Spruce Lake, a small bog lake near Ann Arbor. Aquarium facilities were made available through the courtesy of Prof. F. M. Gaige, Director of the Museum of Zoology, and Dr. Carl L. Hubbs, Curator of Fishes, University of Michigan. Fenton Carbine and John Greenbank, of the Institute staff, assisted in collecting specimens and in conducting water analyses.

Experimental Set-up.--The majority of the experiments were carried on in glass aquaria of twelve liter capacity. Ten liters of water were added to these aquaria, which were then immersed almost to the upper rim in water circulating through large tanks. By adjusting the rate of flow it was possible to maintain a temperature of $60^{\circ} \pm 1^{\circ}$F. A few experiments were carried out in a heated aquarium room at a water temperature of 74°F.

Stock poison suspensions were made by mixing 10 grams of powdered derris root with 1,000 cc. of water. Varying amounts of this stock were used in the different experiments. The derris was purchased from the S. B. Penick Company and was warranted to possess a rotenone content of 5 per cent.

Controls were maintained on all experiments. Effect on various invertebrates was tested by placing them in small screen wire cages immersed in the test solution.

With the exception of goldfish and mud minnows, all of the fish tested displayed a rather uniform type of behavior. The first discernible indication that the poison is being felt comes in the form of a wild, erratic, and apparently uncontrolled dashing and plunging, the

fish moving at top speed, throwing itself blindly into the aquarium walls, and progressing on side or back almost as frequently as in the normal position. This flurry, which may last from 5 to 30 seconds, usually takes the fish to the surface, where it breaks water repeatedly. The fit terminates in a convulsive stiffening of the body, accompanied by uncoordinated twitching of fins and tail. In this condition the fish drifts slowly to the bottom of the tank, coming to rest on its side. Here it may lie, with no movement other than a spasmodic fluttering of the gills, for from 2 to 10 seconds. At the end of this short lapse the fish usually rights itself and swims calmly about in the usual manner, although it may rise to the surface and gulp air repeatedly. Death may not ensue for many hours, during which the above procedure is likely to be repeated several times. On each succeeding occasion the flurry of activity is shorter, and the quiescent period longer in duration. In time a condition verging on paralysis appears. The fish is capable of convulsive movement when strongly stimulated, as by pinching with forceps, but disregards frightening motions made by the observer, and lies still on the bottom or drifts aimlessly with water currents without regard to orientation, the only sign of life being an occasional weak movement of the gills. The actual moment of death is not easily determined. After all detectable response to mechanical stimuli has passed, life may persist. The method of Gersdorff (1937), who confirmed death by dipping the fish into a 1:3 concentration of hydrochloric acid, was adopted in these experiments.

The derris concentrations given in this report are based on the proportion of powdered derris root to water, not the proportion of rotenone to water.

The first three experiments (Table 1) were directed at discovering the speed with which toxicity is dissipated in standing water. The derris suspension was added to an aquarium containing five fish. These died as noted in the table. Twenty hours later two more sunfish were added and killed. Forty-one hours after addition of the poison, two more sunfish were placed in the tank, where they remained for 72 hours without displaying any signs of distress. This led to the conclusion that the toxic effect dropped below the lethal point for sunfish of this size between 20 and 40 hours after poison addition. The average time of death of the first lot is based upon three specimens only. One individual, when almost incapable of movement, was removed to pure, aerated water, and a second treated similarly immediately after it first showed signs of distress and temporary loss of equilibrium. The first of these two died 310 minutes after addition of the derris; the second succumbed after 37 hours, without regaining normal responses or behavior.

In Table 2 are shown the results of decreasing derris concentrations on common sunfish. It will be noted at once that no very great difference between the velocity of fatality in a concentration of 1:1,000,000 and 1:2,000,000. The concentration of 1:4,000,000 proved to be wholly without effect, no sign of distress being detected throughout the 96-hour period of the experiment. This is in sharp contrast with the findings of Scheuring and Heuschmann (op. cit.), who found that a concentration of 1:5,000,000 killed a trout and two perch in an hour and thirty-five minutes, and a rudd in five hours and twenty minutes. In a concentration of 1:10,000,000 they killed two trout in three hours and twenty minutes. From this it seems obvious that their derris root was of considerably higher toxicity than the domestic commercial supply assayed to possess a rotenone content of 5 per cent.

Table 3 sums up four experiments conducted to give a check not only on effect of different concentrations, but also on loss of toxicity by the stock derris suspension (10 grams powdered derris root to 1,000 cc. water). This suspension had been tightly sealed, and stored in darkness. It will be seen that in 10 days time a very slight decrease in toxicity had occurred.

Table 4, comparing time of death of common suckers with that of common shiners, shows the latter to be much the more sensitive of the two toward derris. A comparison with Tables 2 and 3 shows the sensitivity of the common sucker to be about the same as that of the sunfish and bluegills tested.

The high resistance of the mud minnow is clearly shown in Table 5. It was difficult to determine the point at which this species was first affected. At no time did it enter into the violent plunging fit common to most of the others tested, but simply grew gradually and almost imperceptibly more lethargical in its movements. Time of equilibrium loss was also difficult to place accurately, since the fish spent most of its time resting on the bottom of the aquarium, braced by its fins.

Table 6 shows results of a test of toxicity loss by the stock suspension. The poison used in this experiment had been mixed, in the usual proportions, 34 days earlier. Although kept tightly stoppered and in a dark closet, a thin layer of black, evil-smelling mold had formed on the surface. The times of death indicate that during this time the toxicity of the stock suspension had decreased between 60 and 70 per cent.

In the experiments recorded in Table 7, three aquaria were employed. In a large tank twenty goldfish were placed in 20 liters of water, and in a smaller tank ten goldfish were placed in 10 liters of

water. Both of these were held at 60°F. In another small tank, fifteen goldfish were placed in 10 liters of water and kept at 74°F. It will be seen that the fourteen degree elevation of temperature cut the points of equilibrium loss and death to almost one-half the time required at 60°F.

An attempt was made to observe the effect of derris in naturally acid water; to this end a supply of water was obtained from a small bog lake near Ann Arbor. After five goldfish had been left in this water for a 24-hour acclimatization period, a reading of pH 6.5 was made with a Hellige pH outfit. When all the fish had died another reading was made, and the same figure obtained, showing that no change in acidity had taken place. As a control, five goldfish were placed in tap water having a pH of 8.2, and containing the same concentration of derris. The results, recorded in Table 8, show a surprising acceleration in velocity of fatality for individuals in the acid water. Unfortunately, this experiment was interrupted a little over 16 hours after its inception. At this time none of the fish in the alkaline tank had died, but all had lost their equilibrium and would doubtless have succumbed soon.

To supply additional information on the effect of derris on fish in acid water, an experiment was devised using golden shiners, which had already proven to be much more sensitive to derris than goldfish, and brook sticklebacks. The results, shown in Table 9, indicate that the increase in velocity of fatality in acid water is much more marked in the case of resistant species, such as goldfish, than in sensitive fish.

Table 10 shows results of an experiment devised to test loss of toxicity by commercial powdered derris root. Two stock suspensions were made up in the usual proportions, one being prepared with derris received from the manufacturer and unpacked only a few hours before mixing, the other with a lot which had been exposed to air and subdued light over a period of six months. Both lots were obtained from the same manufacturer, and warranted to possess a rotenone content of 5 per cent. On the basis of figures obtained in this test, it was concluded that the six-month-old lot had sustained a loss in toxicity of approximately 43 per cent.

A variety of insects, crustaceans, and snails (see p. 5) were imprisoned in screen wire cages and immersed in a derris concentration of 1:1,000,000, where they were held for 96 hours. At the end of this time, none, not even the stonefly nymphs, showed the slightest sign of distress. Scheuring and Heuschmann (op. cit.) found that most aquatic invertebrates were killed only by very strong concentrations. For example, they found that Chironomus and Gammarus were killed in one or more hours by a concentration of 1:50,000. Daphnia succumbed in from 1 1/2 to 4 hours when exposed to a concentration of 1:200,000. It would therefore appear improbable that a dosage intended to eradicate a fish population would affect the food supply.

An attempt was made to observe the effect of derris on fish eggs. A small number of eyed brown trout eggs was supplied by the Paris State Fish Hatchery. These were divided into two equal lots, one of which was placed in a tank of pure, aerated water, the other in a tank of aerated water containing derris in a concentration of 1:2,000,000. Seventy-two hours later, the eggs in both tanks began to hatch. These in pure water emerged successfully, and swam about. Although about

an equal number hatched in the poison tank, not one was able to free itself completely from the egg. A pair of 1.5-inch bluegills placed in the poison tank were unaffected, but there appeared to be sufficient toxicity to kill the emerging fry. It was obvious that the eggs themselves were not killed by the poison.

Summary

1. In the laboratory toxicity of a 1:1,000,000 concentration of commercial powdered derris root possessing a warranted rotenone content of 5 per cent, dropped below the lethal point for common sunfish and bluegills between 29 and 40 hours.

2. A derris concentration of 1:2,000,000 was only slightly less toxic than one of 1:1,000,000, as tested on common sunfish and bluegills. A concentration of 1:4,000,000 was not lethal to these species.

3. Least resistant to the action of derris of all species tested were: common shiner, golden shiner, bluegill, common sunfish, and brook stickleback. Most strongly resistant were the mud minnow and the goldfish.

4. Goldfish succumbed to the action of derris much more rapidly in acid than in alkaline water. In the case of less resistant species there was no great disparity.

5. After being mixed with water, powdered derris root loses toxicity rather rapidly. Even though protected from light and air, a 1:100 stock suspension lost between 60 and 75 per cent of its toxicity in 34 days.

6. Powdered derris root loses toxicity upon exposure to air. One lot lost approximately 43 per cent of its toxicity over a period of six months during which it was exposed to air and subdued light.

7. A variety of aquatic invertebrates tested were unaffected by exposure to a derris concentration of 1:1,000,000 over a period of 96 hours.

8. Eyed brown trout eggs were not killed in a 1:2,000,000 derris concentration, but the fry perished as soon as they broke the shell, even though the toxicity had by that time dropped below the point lethal to small bluegills.

9. A derris concentration of 1:2,000,000 was found to be most consistent with certainty and economy.

10. Once a fish lost its equilibrium it was doomed, even though transferred to pure water.

TABLE 1. COMMON SUNFISH IN AERATED SPRING WATER, 60°F.

Number used	Average standard length in inches	Concentration in parts per million	Time between addition of derris and start of experiment	Average loss of equilibrium in minutes	Average death in minutes
3	3.5	1:1,000,000	30 minutes	108	220
2	3.5	1:1,000,000	20 hours	38	65
2	3.5	1:1,000,000	40 hours	Alive after 72 hours	

TABLE 2. COMMON SUNFISH IN AERATED SPRING WATER, 60°F.

Number used	Average standard length in inches	Concentration in parts per million	Average loss of equilibrium in minutes	Average death in minutes
2	3.5	1:1,000,000	64	77
2	3.5	1:2,000,000	63	102
2	3.5	1:4,000,000	Both alive after 96 hours	

TABLE 3. BLUEGILLS IN AERATED SPRING WATER, 60°F.

Number used	Average standard length in inches	Concentration in parts per million	Age of stock suspension	Average loss of equilibrium in minutes	Average death in minutes
6	1.8	1:1,000,000	29 hours	35	85
3	1.8	1:2,000,000	4 days	57	102
6	1.6	1:2,000,000	10 days	80	114
5	1.4	1:4,000,000	10 days	109	180[1]

[1] One individual only. Remaining four alive after 96 hours.

TABLE 4. COMMON SUCKER AND COMMON SHINER IN AERATED SPRING WATER, 60°F.

Species	Number used	Average standard length in inches	Concentration in parts per million	Average loss of equilibrium in minutes	Average death in minutes
Shiner	2	2.5	1:2,000,000	35	75
Sucker	2	3.0	1:2,000,000	67	102

TABLE 5. GOLDEN SHINER AND MUD MINNOW

IN AERATED SPRING WATER, 60°F.

Species	Number used	Average standard length in inches	Concentration in parts per million	Average loss of equilibrium in minutes	Average death in minutes
Shiner	2	2.0	1:2,000,000	67	108
Mud minnow	1	3.5	1:2,000,000	528	628

TABLE 6. GOLDEN SHINER, COMMON SUCKER, AND GOLDFISH IN AERATED SPRING WATER, 60°F.

AGE OF STOCK DERRIS SUSPENSION 34 DAYS.

Species	Number used	Average standard length in inches	Concentration in parts per million	Average loss of equilibrium in minutes	Average death in minutes
Shiner	5	2.5	1:2,000,000	83	440
Sucker	2	2.7	1:2,000,000	85	440[1]
Goldfish	5	1.6	1:2,000,000	114	2617

[1] One sucker succumbed after 25 hours and 40 minutes.

TABLE 7. GOLDFISH IN AERATED TAP WATER.

THREE AQUARIA USED, TWO 10-LITER, ONE 20-LITER CAPACITY

Number used	Average standard length in inches	Concentration in parts per million	Water temperature	Average loss of equilibrium in minutes	Average death in minutes
30	1.7	1:2,000,000	60°F.	455	1042
15	1.6	1:2,000,000	74°F.	261	565

TABLE 8. GOLDFISH IN NON-AERATED TAP WATER AND BOG LAKE WATER, 60°F.

Number used	Average standard length in inches	Concentration in parts per million	pH of water	Average loss of equilibrium in minutes	Average death in minutes
5	1.6	1:2,000,000	6.5	184	269
5	1.6	1:2,000,000	8.2	All alive, but equilibrium lost, after 985 minutes	

TABLE 9. GOLDEN SHINERS AND BROOK STICKLEBACKS IN AERATED AND UNAERATED TAP WATER AND UNAERATED BOG LAKE WATER, 60°F., DERRIS CONCENTRATION 1:2,000,000

Species	Number used	Average standard length in inches	Source of water	Average loss of equilibrium in minutes	Average death in minutes
Stickleback	5	1.7	Bog	22	236
Shiner	7	1.6	Bog	20	194
Stickleback	5	1.7	Unaerated tap	35	242
Shiner	4	1.6	Unaerated tap	30	257
Stickleback	6	1.6	Aerated tap	56	267
Shiner	6	1.8	Aerated tap	48	208

TABLE 10. GOLDFISH IN UNAERATED TAP WATER, 60°F.

NEW AND OLD LOTS OF COMMERCIAL DERRIS

Number used	Average standard length in inches	Derris supply	Concentration in parts per million	Average loss of equilibrium in minutes	Average death in minutes
5	1.7	New	1:2,000,000	366	709
5	1.8	Old	1:2,000,000	528	1245[1]

[1] One still alive after 4978 minutes.

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