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SOME USES OF ROTENONE IN FISHERIES MANAGEMENT

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Because of the growing interest in rotenone on the part of fisheries biologists, it has been felt that a brief summary of our present knowledge of it, and comments on past and possible future uses, may be of some value.

Rotenone ($C_{23}H_{22}O_6$), a complex vegetable alkaloid exceedingly toxic to poikilothermous vertebrates, occurs in the roots of a number of tropical and subtropical fabaceous (or leguminous) plants. Commercial supplies, at present almost wholly absorbed by the insecticide industry, are derived from oriental species of *Derris* (= *Deguelia*), known commonly as derris or tuba, and South American species of *Lonchocarpus*, known under various common names such as cubé, timbo, and nicou. Rotenone has been recovered from roots of the common goat's rue, *Cracca* (= *Tephrosia*) *virginiana*, although there are several obstacles to commercial development of this plant as a source of supply.

From historical accounts it appears certain that rotenone was first employed by man as a fish poison, aborigines of Malaysia, Borneo, Sumatra, and various regions of South America all utilizing it in this fashion.

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1 Contribution from Institute for Fisheries Research, Michigan Department of Conservation and University of Michigan.

Dyaks of Sarawak have used in this way for so long that fanciful legends concerning it are woven into their demonology. It also figures as a constituent of various arrow poisons, although present knowledge of its physiological action on warm-blooded vertebrates casts doubt on its individual efficacy in this respect.

It is difficult to determine when the drug was first used as an insecticide. Chinese coolies introduced by early colonizers of the Straits Settlement apparently brought a practical knowledge of its insecticidal uses with them. The first attempt at scientific appraisal of this usage was reported by Oxley in 1848. In 1902 pure rotenone was first obtained in crystalline form by the Japanese chemist Nagai. The last fifteen years have witnessed a tremendous increase in research, principally by insecticide chemists; but until quite recently its original use as a fish poison was all but forgotten.

The exact nature of the drug's physiological action on organisms is still imperfectly understood. Daneel, and Scheuring and Heuschmann have demonstrated a mechanical corrosive action resulting in destruction of gill epithelium by histolysis. These and other investigators have suspected a more fundamental reaction causing paralysis of respiratory motor nerve centers; and although some such action must account for the ease with which frogs, turtles and watersnakes are killed, the exact mechanism is not known. Observations by members of the Institute staff have led us to believe that turtles and watersnakes are killed by eating fish poisoned by rotenone. Piscivorous birds and mammals, such as gulls, mergansers, kingfishers, martens, otters and bears, have been seen to feed on such fish with apparent impunity in Yellowstone Park.

The Institute has had a number of opportunities to employ rotenone during the past five years. Several populations of undesirable fish have been eradicated, and a variety of laboratory experiments conducted. Throughout, we have used powdered derris root supplied by S. B. Penick and Company, and warranted by them to have a content of 5 per cent rotenone and 20 per cent ether extractives, including such toxic substances as deguelin, tephrosin and toxicarol. Further experiments pending are designed to compare the efficiency of powdered derris root with that of powdered timbo, the South American product, which is considerably less expensive.

Some of the conclusions arrived at from earlier experiments might be given at this time:

1. The minimum dosage of derris consistent with certainty of kill for all species tested is 1:2,000,000 at 60°F. (This and following figures refer to derris powder with five per cent rotenone content, <u>not</u> to pure rotenone.)
2. Least resistant 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.
3. 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.
4. An increase in water temperature from 60° to 74°F. almost halved the time of death, or velocity of fatality.
5. Toxicity of a 1:1,000,000 concentration fell below the point lethal to fish somewhere between 30 and 40 hours after the poison was added.

6. Various aquatic invertebrates, including mayfly and stonefly nymphs, scuds, crayfish, cranefly and caddisfly larve, and water boatmen, were unaffected after exposure to a 1:1,000,000 concentration for 96 hours.

7. Powdered derris root loses toxicity rather rapidly upon exposure to either air or sunlight. One lot exposed to air but kept in subdued light lost about 43 per cent of its toxicity over a period of six months. Supplies should be kept in tightly sealed, opaque jars or cans. Aqueous stock suspensions lose toxicity rather rapidly after about twenty hours, but may with advantage be mixed about twelve hours before use, to insure complete dispersal of the exceedingly minute, insoluble particles of derris.

The uses of rotenone in fisheries management are numerous and varied; and new uses and improved techniques continue to be developed. Based upon our own experiences, we have concluded that the best method of application consists of mixing powder and water in a tub, fish can or similar large container, until the resulting suspension has the consistency of thin batter. It must be remembered that rotenone is insoluble in water. Great care must be taken therefore to break up and thoroughly moisten all lumps of powder. It is well to mix the required amount a few hours (up to twelve) before use to insure complete mixing. When treating a lake, rapid and wide dispersal may be achieved by pouring the mixture into the wake of an outboard motor. In deep lakes, dynamite bombs detonated at the bottom accelerate distribution. Irregularities of shore line, weedy inlets, and so forth, may be treated conveniently by spraying the batter from a fire fighter's back-pump.

Use of rotenone has greatly aided several of our projects. One of its first applications was to a series of small, deep, so-called pot-hole lakes in northern Michigan, where yellow perch, through too successful reproduction, increased beyond the carrying capacity of the existing food supply, and as a result became dwarfed until a fish of legal size could hardly be found in them. Some of these stunted populations were eradicated, and a fresh start made by stocking more desirable species in numbers better scaled to coincide with the available food supply. Rotenone was obviously preferable to copper sulphate, calcium hypochlorite or chlorinated lime, because the latter chemicals would have destroyed or seriously damaged existing aquatic vegetation and food organisms, none of which are harmed by rotenone in concentrations lethal to fish. These experiments have given most gratifying results.

In other instances, undesirable species have been expunged. Several private waters poisoned under Institute supervision have been ridded of unwanted hordes of goldfish and, in one case, of a superabundant population of frogs whose nocturnal revels interfered with those of the property owner. A small stream feeding a bluegill rearing pond became overrun with small black bullheads which dropped downstream into the pond and made sorting a long and tedious process. After the bluegills were removed during the stocking season the pond was drained, closed off, and the stream above treated with derris. Subsequently the water was allowed to collect in the pond until its toxicity subsided.

Near Ann Arbor, parasitization of fish, especially large-mouth bass, bluegills and sunfish, became so heavy as to stifle fishing interest in what had previously been a popular ten-acre lake. Derris treatment was resorted to with the dual objective of securing materials for a population study and reducing parasitization by removing one of the required hosts. Unfortunately the volume of water present was underestimated, with the result that a 100 per cent kill was not obtained. Subsequent recalculation showed the concentration to have been only about 1:3,750,000 instead of 1:2,000,000, as anticipated. It is planned to repeat the poisoning, then leave the lake unstocked for a year or two in the hope of reducing parasitization to a minimum.

In Goose Lake, Yellowstone National Park, La Noue reports obtaining an apparently complete kill of a dwarfed population of yellow perch. This body of water, 37.5 acres in area and with a maximum depth of 25 feet, is one of the largest poisoned to date. Outboard motors and bombs were used to secure rapid and complete dispersal of derris, which was used in a concentration of approximately 1:1,750,000.

In Fish Lake, Utah, Dr. Stillman Wright is reported to have had good success in controlling an overabundant population of the squawfish, *Tigoma*, by poisoning shoal areas with derris during the spawning season of the fish. His methods have not as yet been recorded. If poisoning of restricted portions of a large body of water can be done without danger to desirable fishes occupying adjoining areas, an entire new sector will be added to the scope of derris's usefulness.

Methods for controlling the action of derris in streams are not at all well developed, largely because the great dangers attendant upon the possibility of toxicity persisting beyond the desired limits and seriously affecting desirable populations have made workers reluctant to experiment. In a few instances the Institute has treated streams flowing into lakes or ponds also to be treated. Our practice has been to throw a temporary dam across the channel at the upper end of the section, add enough derris suspension to the impounded water to equal a 1:2,000,000 concentration for all the water in the section at a given tiem, then rip out the dam and allow the highly concentrated poison to sweep down the stream. This method seems to have been successful; but poisoning of streams which cannot practicably be impounded is both difficult and dangerous.

In summary it may be said that derris has proven itself to be of great value in certain phases of fisheries management such as:

1. Securing an entire population for study of such problems as sex ratio, growth rate, condition factor, and normal representation of the various age classes.
2. Eradication of undesirable populations of
    a. Stunted fish
    b. Heavily parasitized fish
    c. Populations dominated by coarse or otherwise undesirable species.

In order to expand and further clarify our understanding of its various applications, experimental work, in field and laboratory, is an affair of necessity. Some of the problems we already recognize are:

1. Effect and possible buffer action upon toxicity of large amounts of organic materials, as in mucky bottom lakes.
2. Possible effects on toxicity of abundant weed beds.
3. Further observations on effect of acidity or alkalinity and relative hardness of water.
4. Need for more accurate and complete tables of dosages for different species of fish at different water temperatures.
5. More complete understanding of the physiological action of the drug on various organisms. It is particularly desirable to learn whether or not any injury might accrue to livestock drinking treated water, and to know more of the possible effects on various animals devouring fish poisoned with derris.

So useful are rotenone-containing compounds in fisheries management that information concerning them should be available to all qualified fisheries investigators. It is hardly necessary to point out, however, that the drug remains a menace to freshwater fisheries. Thus far, the general public seems not to be aware of its fish-killing properties. It is so widely advertised as an insecticide, however, that we cannot depend on an indefinite continuation of this happy state of ignorance. Conservation administrators might well be giving thought to the introduction of methods for legal control of sale.

INSTITUTE FOR FISHERIES RESEARCH

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