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EFFECTIVENESS OF VARIOUS ROTENONE-CONTAINING PREPARATIONS IN ERADICATING FARM POND FISH POPULATIONS

by

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Abstract

A comparison of 4 different rotenone-containing products based on their effectiveness in eradicating fish populations was made in 56 Kentucky farm ponds representative of various seasonal conditions. The studies revealed that complete fish population eradication was most successful during the summer period of June through mid-September. A total of 24 ponds were treated during the summer and 97% of these treatments resulted in complete elimination of the fish populations. During the fall, a total of 32 ponds were treated and only 72% of these treatments were completely successful.

Rotenone penetration was investigated in 38 of the 56 ponds and was found to be essentially the same in ponds treated during the fall overturn period, October and November, as it was in ponds that were thermally stratified. The maximum depth to which rotenone penetrated in amounts lethal to fish was 8 feet, regardless of the prevailing water conditions. However, it is believed that oxygen depletion in the lower waters (stagnation) during the summer months prevented fish from remaining below the zone of rotenone penetration and thereby made treatment more effective at that time.

The yellow bullhead, Ictalurus natalis, was the most difficult species to eliminate of all those encountered during the investigations.

Introduction

Since the pioneer work on the use of powdered derris root for eliminating undesirable fish populations from 2 Michigan ponds in 1934 (Krumholz 1948, Solman 1950), numerous rotenone-containing compounds have been developed expressly for use in fisheries research and management. The use of rotenone-containing compounds for the eradication of undesirable fish populations was introduced to Kentucky in 1947 when a farm pond near Hopkinsville was treated with powdered cubé (5% rotenone) by the Division of Fish and Game. The practice of reclaiming farm-pond fish populations through the use of rotenone-containing preparations steadily increased, and in 1949 a total of 95 ponds were treated in Kentucky. Since 1950, an annual average of 171 ponds have been treated with various rotenone compounds.

In the meantime, other practices, such as selective poisoning and partial poisoning, have stemmed from the use of rotenone compounds as fish toxicants. Along with these practices came the development of a multitude of improved rotenone products, each designed to fulfill the requirements of various and particular jobs.

In 1956, the Kentucky Department of Fish and Wildlife Resources realized the need to determine which rotenone products served best for the total eradication of pond fish populations. A project was initiated in conjunction with the U. S. Fish and Wildlife Service (D.-J. Project F-10-R) and motivated the field testing of rotenone products under various seasonal conditions.

Materials and Methods

During the period from May 1956 to November 1958, the fish populations in 56 farm ponds, located throughout the State, were treated with various rotenone-containing compounds at a concentration of 1.0 ppm. by volume. The studies were based on the use of 3 different rotenone emulsives and 1 type of rotenone powder; Pro-Noxfish, Chem-Fish Regular, Chem-Fish Special, and powdered cubé (5% rotenone).

Study ponds were selected from applications for chemical treatment on file in the central office of the Kentucky Department of Fish and Wildlife Resources at Frankfort.

Prior to treatment with rotenone, the surface area of each pond was estimated. If a reasonable estimate could not be obtained, the pond was mapped using the plane-table method and the surface area computed therefrom. Each pond was sounded to determine the maximum and average depth, and the volume of water was calculated. Physico-chemical determinations were made in 49 of the ponds and included measurements of total alkalinity, dissolved oxygen, and pH. Complete temperature profiles were recorded from the region of maximum depth with a Whitney Underwater Thermometer.

The previously mentioned rotenone products were mixed with water at the rate of 10 parts water to 1 part emulsive or powder (approximate) and sprayed over the surface of the ponds by means of a gasoline-driven centrifugal pump. Following the application of rotenone, the kinds and relative abundance of each species that surfaced were recorded.

Subsequent to treatment an attempt was made to determine the vertical distribution of rotenone in the ponds. Controlled biological tests were made by introducing live bluntnose minnows, Pimephales notatus, into water samples taken from various depths at regular time intervals after treatment. The water samples were aerated with an oxygen-producing tablet ("O-Tabs" - Pemble Laboratories, River Falls, Wisconsin) to insure that death did not result from oxygen deficiency. The observed activity and the amount of time required to kill the test fish were recorded and used as an index to the degree of toxicity of the waters. If death resulted within 2 hours after the introduction of the test fish, the sample was considered as toxic. If the test fish showed considerable distress but lived for more than 2 hours the water was classified as mildly toxic. If the test fish showed no signs of distress within 2 hours the sample was considered non-toxic. There was not enough time to perform chemical tests, such as chloroform extractions.

From 1 to 6 months later the ponds were investigated in order to determine the effectiveness of the treatment. During the summer months the ponds were checked for live fish by shoreline observation, extensive seining, and by spot-poisoning with rotenone in small areas. If live fish were detected by any of these methods the pond was re-treated with rotenone at a concentration of 2.0 ppm. The different species and the abundance of the fish that survived the initial treatment were noted. During the fall and winter months all ponds were checked by re-treatment with 2.0 ppm.

of Chem-Fish Special, an emulsifiable rotenone preparation especially developed for use in cold waters. The checking methods employed during this study were not by any means infallible but were the most practical ones at our disposal. Draining the ponds would be a more reliable method of checking the success of treatment but is far less expedient.

Pond Treatment

A total of 56 farm ponds were treated with various rotenone-containing products during the summer and fall seasons of 1956, 1957, and 1958. A concentration of 1.0 ppm. (by volume) of rotenone was used in each of the ponds. The comparative effectiveness of the various rotenone products as used during the summer and fall is summarized in Table I.

Five ponds were treated with powdered cubé (5% rotenone) during the summer of 1956. The fish populations were completely eradicated from all 5 ponds.

During the summers of 1956 and 1957, a total of 12 ponds were treated with Pro-Noxfish. Pro-Noxfish is an emulsifiable concentrate prepared by S. B. Penick and Co. and contains 2.5% rotenone and 2.5% synergist (sulfoxide). In specific terms, the sulfoxide is an activator which, when combined with rotenone, produces a greater effect than the sum of the 2 effects evaluated independently.

The fish populations were completely eliminated from 11 of the 12 ponds that were treated. This represents a 91% killing efficiency based on the use of Pro-Noxfish during the summertime.

Pro-Noxfish was also employed in the treatment of 18 ponds during the falls of 1957 and 1958. The fish populations were totally eradicated in 12 of the ponds, which represents a 67% killing efficiency based on the use of this product during the fall of the year.

Table I. Effectiveness of various rotenone-containing products based on the percentage of complete kills obtained during the summer and fall treatments of 56 ponds at a concentration of 1.0 ppm.

Rotenone preparation	No. of ponds treated		Efficiency of summer treatment (%)	Efficiency of fall treatment (%)	Over-all efficiency (%)
	Summer	Fall			
Powdered cubé	5		100		100
Pro-Noxfish	12	18	91	67	79
Chem-Fish Reg.	7		100		100
Chem-Fish Spec.		14		78	78
Totals (Avg.)	24	32	(97)	(72)	(89)

A total of 30 ponds were treated with Pro-Noxfish and complete fish kills were realized in 23 of these ponds for an over-all efficiency of 79%.

The fish populations were completely eradicated from 7 ponds treated with Chem-Fish Regular during the summer of 1958. Chem-Fish Regular is a standard 5% rotenone emulsive prepared by Chemical Insecticide Corporation.

The fish populations in 14 ponds were treated with Chem-Fish Special during the fall of 1957. Complete kills were realized in 11 of these ponds, which represents an efficiency of 78 per cent. Rainfall is the factor that probably limited the success of this product during the fall treatment program. Heavy downpours during 2 of the treatments supplied enough incoming runoff waters to interfere with the success of the treatments. Live fish were observed congregating near the areas of incoming fresh water on the day following treatment.

Chem-Fish Special is a 5% rotenone formulation and is reportedly heavier than the standard 5% rotenone emulsives. It was designed especially for the treatment of cold, deep bodies of water.

Considering the treatment of all 56 ponds during both summer and fall, a killing efficiency of 89% was obtained. A total of 97% of the 24 ponds treated during the summer resulted in complete eradication of the fish populations, whereas, the elimination of fish was completely successful in only 72% of the 32 ponds treated during the fall. Seasonal differences affecting conditions within the ponds were apparently limiting factors to the successful elimination of fish populations rather than selection of the proper rotenone products.

Vertical Distribution of Rotenone

Temperatures recorded in a vertical series from the regions of maximum depth in 17 ponds treated during the summers of 1957 and 1958 revealed the presence of thermal stratification, Tables II and III. The hypolimnion was absent in all of the ponds and in 5 of the ponds the thermocline extended from the surface to the bottom. The epilimnion, when present, was usually shallow and was restricted to the upper 3 feet of water in all but 3 ponds. In pond 57-6, which had a maximum depth of 9 feet, the epilimnion extended to a depth of 8 feet. This was probably due to thorough mixing of the waters by wind action, as indicated by the high concentration of dissolved oxygen at the middle and bottom of the pond, Table IV. In ponds 58-21 and 58-23, the epilimnion was somewhat deeper than in most of the ponds.

Other physico-chemical data collected from the 17 ponds are summarized in Table IV. Total alkalinities in the ponds ranged from 12 to 103 ppm., and pH recordings ranged from 6.8 to 8.6.

Summer stagnation occurred in all but 1 of the ponds as evidenced by the lack of dissolved oxygen in the lower waters. The complete mixing of the waters in pond 57-6 has already been mentioned.

Table II. Temperature profiles taken at the area of maximum depth in 10 ponds treated during the summer of 1957.

Pond	Sampling date	Temperature (°F) at 1 foot intervals																		
		S	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
57-1	8 Aug.	*91.2	89.0	84.2	82.2	80.2	78.1	76.8	72.5	69.1	67.2									
57-2	15 Aug.	*93.5	87.4	83.7	81.8	80.5	76.7	73.5	70.6	66.2	65.0									
57-3	5 July	78.8	78.8	*78.8	78.2	76.4	71.6	68.0	66.5	65.5	65.0									
57-4	11 July	81.8	*81.6	78.8	78.0	77.0	75.9	73.6	70.2	66.0	62.2	60.2	57.2	56.0	55.2	54.7				
57-5	18 July	79.1	79.0	78.8	*78.6	76.8	73.4	69.4	66.7	64.6	62.7									
57-6	25 July	82.6	82.6	82.4	82.2	82.0	81.8	81.5	81.4	*81.3	78.6									
57-7	23 Aug.	76.0	*75.6	74.6	73.3	73.0	72.2	71.6	70.6											
57-8	12 June	75.7	*75.4	74.0	73.8	73.6	73.4	73.1												
57-9	19 June	82.6	82.6	82.4	*82.4	77.1	77.0	66.1	62.8	61.4	60.4	57.6								
57-10	2 Aug.	*86.6	86.0	83.9	83.2	82.8	81.0	77.7	75.6	73.6	71.2	66.7	64.8	62.4	59.1	56.8	55.5	54.3	53.0	52.1

* Denotes upper limit of thermocline as based on the standard change of 0.548° F. per foot.

Table III. Temperature profiles of 7 ponds treated during the summer of 1958.

Pond	Sampling date	Temperature(°F) at 1 foot intervals														
		S	1	2	3	4	5	6	7	8	9	10	11	12	13	14
58-17	9 July	*84.0	80.6	74.4	73.1	71.9	65.9	63.8	60.8	56.4	56.0					
58-18	20 Aug.	83.8	*83.8	82.7	82.0	81.0	80.3									
58-19	3 Sept.	84.3	*84.3	82.3	81.2	76.4	76.2	76.1	76.1	76.0	75.3	74.1	72.2	71.6	70.5	
58-20	23 July	*83.9	82.1	80.3	75.3	74.6	73.9	72.4	65.9	63.8	61.1	54.8	54.0	53.7		
58-21	1 Aug.	83.6	83.3	83.0	82.9	82.7	*82.5	76.8	74.3	71.8	66.5	65.2	64.4	63.5	62.6	61.4
58-22	18 June	77.0	76.9	*76.8	73.4	71.0	66.4	63.2	60.4	54.6	53.2	51.8	51.2	50.9		
58-23	14 Aug.	82.8	82.8	82.8	82.8	82.7	82.6	*82.3	81.2	75.4	73.1	66.8				

* Denotes upper limit of thermocline as based on the standard change of 0.548° F. per foot.

Table IV. Chemical data collected from 17 ponds treated during the summers of 1957 and 1958.

Pond	Total alkalinity (ppm.)	Dissolved oxygen (ppm.)			pH	Evaluation of kill
		Top	Middle	Bottom		
57-1	52	10.9	9.9	3.1	7.8	Complete
57-2	48	9.1	1.7	1.4	6.8	Complete
57-3	50	5.2	2.3	0	7.2	Complete
57-4	103	8.9	2.1	0	8.3	Complete
57-5	65	7.0	5.2	0.2	8.6	Complete
57-6	39	7.0	6.8	6.8	8.6	Complete
57-7	76	8.1	4.1	0	7.9	Complete
57-8	87	5.2	3.7	3.3	8.3	Complete
57-9	96	7.9	1.7	0.4	7.3	Complete
57-10	52	11.4	1.0	0	8.7	Incomplete
58-17	12	7.3	3.2	0	6.8	Complete
58-18	21	-	7.7	-	8.1	Complete
58-19	30	6.7	6.5	0	7.8	Complete
58-20	38	8.3	5.5	1.6	7.3	Complete
58-21	73	7.1	4.4	0	7.2	Complete
58-22	17	7.3	3.8	0	7.3	Complete
58-23	19	6.3	5.7	0.6	7.7	Complete

Pond 57-10 is the only pond treated during the summer that resulted in an incomplete fish kill. The maximum depth of this pond was 18 feet, and at a depth of 9 feet, there was 1.0 ppm. of dissolved oxygen. The vertical distribution of rotenone was not checked in this particular pond, but tests with live minnows used during the treatment of 7 other summer ponds indicated a maximum rotenone penetration of 8 feet (pond 56-8) in sufficient amounts to assure killing fish, Table V. Test minnows lived

Table V. Vertical dispersion of rotenone emulsives in 7 ponds treated during the summers of 1956 and 1958.

Pond	Maximum depth (feet)	Relative toxicity at various levels								
		3 hours			24 hours			45 hours		
		Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower
56-7	13	++	++	-	++	++	-	++	++	-
56-8	8	++	++	++	++	++	++	++	++	++
58-17	9	++	++	-	++	++	-	++	++	-
58-19	13	++	++	-	+	+	-	+	+	-
58-20	12	++	++	-	++	++	-	++	++	-
58-21	14	++	++	-	++	++	-	++	++	-
58-22	12	++	++	-	++	++	-	++	++	-

++ indicates toxic, + mildly toxic, and - non-toxic.

indefinitely in water samples taken from near the bottom of all ponds 3 hours subsequent to the application of rotenone, except 56-8. Chemical determinations of the waters were not made in ponds 56-7 and 56-8, but eradication of the fish populations was evaluated as complete in both.

Water samples taken 24 hours after treatment revealed that rotenone had not penetrated to the bottom in 6 of the 7 ponds that were tested. In pond 58-19, the waters tested as being mildly toxic at the surface and middle and still non-toxic at the bottom after 24 hours.

The rotenone emulsives had not penetrated below the middle (below 5 to 7 feet) in any of the ponds except 56-8, 45 hours after treatment. A similar rotenone penetration pattern was illustrated by Clemens and Martin (1952) in Oklahoma farm ponds. They found that by agitating the waters with an outboard motor the rotenone penetrated to a depth of 6 feet in amounts lethal to test minnows and enough to 9 feet to cause distress to fish. Rotenone in non-agitated ponds penetrated to a depth of only 5 feet. The ponds discussed in the present paper were all treated from a boat powered by an outboard motor which agitated the waters as the rotenone was being applied.

At first, the reason for the shallow penetration of rotenone was attributed to the greater density and lack of circulation in the lower waters, Kirkwood and Turner (1957). However, studies made later during the fall circulation period revealed similar shallow rotenone penetration in unstratified ponds. On the basis of both summer and fall studies, it appears that a very small amount of rotenone penetrates into the deeper waters. However, during the summer treatment of ponds it is usually non-essential that the rotenone penetrate into the deeper waters as there is not enough dissolved oxygen present at these depths to sustain fish life for any appreciable length of time.

A total of 32 ponds were treated with 1.0 ppm. of a rotenone-containing product between 30 September and 14 November to determine whether or not penetration was any greater under fall conditions. During that period the waters were undergoing the process of complete circulation. A nearly homeothermous condition existed in the majority of the ponds or, at most, there was a relatively shallow layer of warmer water at the surface due to insolation, Tables VI and VII.

High concentrations of dissolved oxygen in the deeper waters further substantiates the occurrence of complete circulation (Tables VIII and IX). Pond 57-26 was unique in that more dissolved oxygen was present near the bottom than in the surface waters. This may likely be attributed to plant growth on the bottom of the pond. In 5 of the ponds dissolved oxygen determinations were made at the middle depth only. These ponds were extremely shallow and but 1 vertical water sample was practicable.

The total alkalinities in the ponds treated during the fall ranged from 14 to 124 ppm., and pH recordings ranged from 7.1 to 9.0.

The vertical distribution of rotenone was checked in 31 of the 32 ponds treated during the fall, Tables X and XI. Water samples taken 3 hours after treatment disclosed that the maximum rotenone penetration, in amounts lethal to test minnows, was 7 feet (pond 58-15). Enough rotenone to cause distress to the test minnows had penetrated to a depth of 10 feet in ponds 58-1 and 58-6. Most likely an error was made in the calculation of rotenone needed to treat pond 58-5, as even the surface waters were not toxic enough to kill fish 3 hours after application. After 24 hours the surface waters of this pond were decidedly non-toxic.

Toxicity of the waters was checked 45 hours after treatment in 12 ponds. The surface waters in 7 of these ponds were still definitely toxic

Table VI. Temperature profiles of 16 ponds treated during the fall of 1957.

Pond	Sampling date	Temperature (°F) at 1 foot intervals								
		S	1	2	3	4	5	6	7	8
57-11	30 Sept.	72.2	67.8	65.4	64.7	64.4	64.4	64.4	64.4	64.4
57-12	8 Oct.	71.6	64.5	62.4	62.2	62.2	62.1	62.1		
57-13	2 Oct.	76.0	75.1	70.4	68.2	67.2	66.8			
57-14	9 Oct.	62.3	60.6	60.4	60.4					
57-15	14 Oct.	59.0	55.4	54.4	54.2	54.2				
57-16	14 Oct.	62.0	56.2	55.8	55.4	55.4				
57-17	15 Oct.	58.5	58.3	58.3	58.3	58.0	58.0			
57-18	15 Oct.	59.3	59.2	59.2	59.2	58.9	58.2	58.2		
57-19	16 Oct.	62.9	62.9	62.9						
57-20	17 Oct.	64.2	64.1	64.0	63.3					
57-21	17 Oct.	64.6	64.6	64.6	64.6					
57-22	18 Oct.	61.8	61.8	61.6	61.4	61.0	60.6	60.6	60.6	
57-23	21 Oct.	56.6	54.8	53.6	53.2	53.2				
57-24	22 Oct.	56.8	56.2	55.8	55.6	55.6				
57-25	22 Oct.	56.4	56.4	56.3	55.6	55.2	55.0	54.6	54.4	54.4
57-26	28 Oct.	48.2	48.2	48.2	48.2	47.6	47.4	47.0	47.0	47.0

Table VII. Temperature profiles taken at the area of maximum depth in 16 ponds treated during the fall of 1958.

Pond	Sampling date	Temperature (°F) at 1 foot intervals																
		S	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	23
58-1	9 Oct.	71.7	71.2	70.7	70.3	68.9	68.0	67.0	66.8	65.9	65.6	65.1						
58-2	13 Oct.	58.3	58.2	58.0	57.6	57.4	57.3	57.3	57.2	57.2	57.2	57.2	57.2	57.2				
58-3	13 Oct.	66.0	65.8	65.5	65.4	65.4	65.4	65.4	65.4									
58-4	14 Oct.	61.8	61.8	61.6	61.3	61.2	61.2	61.2	61.2	61.2	61.2							
58-5	27 Oct.	57.4	57.4	57.3	57.2	56.9	56.5	56.3										
58-6	28 Oct.	57.4	57.3	57.3	57.3	57.2	57.2	57.1	57.1	57.0	57.0	57.0						
58-7	29 Oct.	56.6	56.4	56.4	56.2	56.0	55.6	55.3	55.2	55.0	54.8	54.6	54.4	54.3	54.1	54.0		
58-8	29 Oct.	56.8	56.3	55.9	55.7													
58-9	3 Nov.	57.8	57.4	55.4	54.8	54.8	54.7											
58-10	4 Nov.	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0
58-11	4 Nov.	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2			
58-12	4 Nov.	58.8	58.4	58.4	58.0	57.8	57.7	57.3	57.2	57.2								
58-13	4 Nov.	55.6	55.4	55.4	55.4	55.2	55.0	54.4										
58-14	5 Nov.	55.3	55.2	55.2	55.2	55.2	55.1	55.1	55.1	55.1	55.1							
58-15	5 Nov.	56.1	56.1	56.1	56.0	56.0	56.0	56.0	56.0									
58-16	14 Nov.	53.4	53.4	51.2	49.4	48.8	48.8	48.6	48.6	48.6	48.6	48.6	48.6	48.6	48.6	48.6		

Table VIII. Chemical data collected from 16 ponds treated during the fall of 1957.

Pond	Total alkalinity (ppm.)	Dissolved oxygen (ppm.)			pH	Evaluation of kill
		Top	Middle	Bottom		
57-11	39	8.5	7.4	6.8	8.4	Complete
57-12	33	6.0	5.6	5.2	7.4	Complete
57-13	43	9.3	7.9	7.8	8.3	Incomplete
57-14	33	-	6.2	-	7.2	Complete
57-15	65	9.7	9.6	9.6	8.5	Complete
57-16	92	2.0	1.9	1.9	7.6	Complete
57-17	111	3.9	3.7	3.7	7.5	Complete
57-18	124	3.6	3.5	3.4	7.3	Complete
57-19	33	-	8.0	-	7.8	Complete
57-20	39	-	9.3	-	7.6	Complete
57-21	72	-	7.9	-	7.8	Complete
57-22	37	7.6	7.2	7.2	7.7	Complete
57-23	59	8.5	8.3	8.3	8.6	Complete
57-24	55	8.0	7.8	7.7	8.3	Complete
57-25	85	10.3	8.3	8.0	8.8	Incomplete
57-26	72	8.5	8.7	9.5	9.0	Incomplete

Table IX. Chemical data collected from 16 ponds treated during the fall of 1958.

Pond	Total alkalinity (ppm.)	Dissolved oxygen (ppm.)			pH	Evaluation of kill
		Top	Middle	Bottom		
58-1	14	8.9	8.7	8.5	7.1	Complete
58-2	101	6.3	5.9	5.7	8.1	Complete
58-3	92	7.3	7.2	6.7	8.0	Incomplete
58-4	86	6.7	6.7	6.5	7.3	Complete
58-5	38	9.8	9.5	9.1	7.4	Incomplete
58-6	24	6.6	6.4	5.9	7.6	Complete
58-7	32	7.9	7.8	7.7	7.4	Incomplete
58-8	37	-	10.3	-	7.8	Complete
58-9	35	7.0	6.9	6.7	7.3	Complete
58-10	96	8.1	6.1	1.2	7.5	Incomplete
58-11	88	7.1	7.1	6.7	7.9	Incomplete
58-12	37	5.9	5.9	5.9	7.7	Complete
58-13	15	9.0	9.0	8.9	7.2	Complete
58-14	50	7.2	7.0	6.9	8.0	Complete
58-15	33	9.4	9.4	9.1	7.7	Complete
58-16	60	6.7	6.5	5.9	7.6	Incomplete

Table X. Vertical dispersion of rotenone emulsives in 17 ponds treated during the fall of 1957.

Pond	Maximum depth (feet)	Relative toxicity at various levels								
		3 hours			24 hours			45 hours		
		Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower
57-11	8	++	-	-	++	-	-	+	+	-
57-12	6	++		-	++		+	++		+
57-13	5	++		-	+		+	-		-
57-14	3		++			++				
57-15	4		++			++				
57-16	4		++			++				
57-17	5	++		++	++		++			
57-18	6	++	++	+	++	++	+			
57-19	2		++			++				
57-20	3		++			++				
57-21	3		++			++				
57-22	7	++	-	-	++	++	+			
57-23	4		++			++				
57-24	4		++			++				
57-25	8	++	+	-	++	+	-	++	+	-
57-26	8	++	+	-	++	+	-	++	+	-

++ indicates toxic, + mildly toxic, and - non-toxic.

Table XI. Vertical dispersion of rotenone emulsives in 14 ponds treated during the fall of 1958.

Pond	Maximum depth (feet)	Relative toxicity at various levels								
		3 hours			24 hours			45 hours		
		Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower
58-1	10	++	++	+	++	+	+			
58-2	12	++	++	–	++	++	–	++	+	–
58-3	7	++		+	+		+	+		–
58-4	9	++	++	+	++	+	+			
58-5	6	+		–	–		–	–		–
58-6	10	++	++	+	++	++	+			
58-7	15	++	+	–	++	+	–			
58-8	3		++			++				
58-9	5	++		++	++		++	++		+
58-10	23	++	–	–	+	–	–	+	–	–
58-11	13	++	+	–	++	+	–	++	–	–
58-13	7	++		+	++		+			
58-15	7	++		++	++		++			
58-16	15	++	+	–	++	–	–	++	–	–

++ indicates toxic, + mildly toxic, and – non-toxic.

at that time. Water samples taken from near the bottoms were non-toxic in 10 of the ponds and mildly toxic in 2 of the shallower ponds.

The maximum rotenone penetration in amounts lethal to fish was determined as 7 feet in the ponds treated during the fall, whereas a rotenone penetration of 8 feet was the maximum detected in the ponds treated during the summer. The occurrence of thermal stratification seemed to have little effect on the vertical distribution of rotenone in the ponds, but fall circulation apparently had a reverse effect on the success of treatment. Based on these findings it would be advantageous to treat fish populations during the summer months when stagnation occurs. Rotenone penetration to any great depths is unnecessary during the stagnation period as fish movements are usually restricted to the upper waters.

Nine of the 32 ponds treated during the fall resulted in incomplete fish kills. This represents a fall treatment efficiency of 72% as compared to 97% efficiency obtained during the summer treatment of 24 ponds.

Effectiveness of Rotenone on Various Species of Fishes

A total of 28 species of fishes were noted in the 56 ponds treated with rotenone. The frequency of their occurrence in these ponds, frequency of survival, and the relative success of kill for each species are presented in Table XII.

The yellow bullhead, Ictalurus natalis, was the most difficult species to kill of all those encountered during the investigations. This species was successfully eliminated from 69% of the 16 ponds in which they occurred. Bullheads have previously been shown by Krumholz (1950) to be very resistant to rotenone. Goldfish, Carassius auratus, was the second most difficult species to kill and were completely eliminated from 75% of the ponds in which they occurred. Green sunfish, Lepomis cyanellus, were successfully

Table XII. List of fishes occurring in 56 ponds treated with 1.0 ppm. of various rotenone-containing products during 1956, 1957, and 1958, showing their frequency of occurrence, frequency of survival, and the success of kill.

Scientific name	Common name	Occurrence (no. ponds)	Survival (no. ponds)	Killing success (% ponds)
Dorosoma cepedianum	Gizzard shad	2	0	100
Catostomus commersoni	White sucker	1	0	100
Ictiobus bubalus	Smallmouth buffalo	1	0	100
Ictiobus cyprinellus	Bigmouth buffalo	1	0	100
Campostoma anomalum	Stoneroller	1	0	100
Carassius auratus	Goldfish	4	1	75
Cyprinus carpio	Carp	10	0	100
Hybopsis storeriana	Silver chub	1	0	100
Notemigonus chrysoleucas	Golden shiner	9	0	100
Pimephales notatus	Bluntnose minnow	1	0	100
Pimephales promelas	Fathead minnow	3	0	100
Semotilus atromaculatus	Creek chub	1	1	0
Ictalurus melas	Black bullhead	9	1	89
Ictalurus natalis	Yellow bullhead	16	5	69
Ictalurus nebulosus	Brown bullhead	1	0	100
Ictalurus furcatus	Blue catfish	1	0	100
Ictalurus punctatus	Channel catfish	6	0	100
Pilodictis olivaris	Flathead catfish	1	0	100
Gambusia affinis	Gambusia	3	0	100
Chaenobryttus gulosus	Warmouth	5	0	100
Lepomis cyanellus	Green sunfish	29	4	86
Lepomis macrochirus	Bluegill	45	3	93
Lepomis megalotis	Longear sunfish	4	0	100
Lepomis microlophus	Redear sunfish	2	0	100
Micropterus salmoides	Largemouth bass	33	0	100
Pomoxis annularis	White crappie	15	0	100
Pomoxis nigromaculatus	Black crappie	1	0	100
Aplodinotus grunniens	Freshwater drum	1	0	100

eliminated from 86% of the 29 ponds in which they occurred. Black bullheads, *Ictalurus melas*, were completely eradicated from 89% of the ponds in which they occurred.

Bluegill, *Lepomis macrochirus*, occurred in more ponds than did any other species of fish. Most of the ponds were originally stocked with combinations of largemouth bass, *Micropterus salmoides*, and bluegill. Bluegill were successfully eliminated from all but 3 of the 45 ponds in which they occurred, which represents a 93% effective removal of that species. Largemouth bass were completely eliminated from all 33 ponds in which they occurred. White crappie, *Pomoxis annularis*, were also very responsive to rotenone treatment and were totally eliminated from the 15 ponds in which they were present. All other species were entirely eliminated from the ponds or occurred in too few ponds to represent a valid comparison.

Discussion and Conclusions

Field tests based on the success of treatment and the degree of vertical penetration of 4 well known brands of rotenone-containing fish toxicants in 56 farm ponds revealed that 1.0 ppm. of rotenone (by volume) is sufficient for the complete eradication of undesirable pond fish populations, regardless of the product used.

There was no significant difference in the degree of rotenone penetration in ponds treated during the fall of the year than in those treated during the summer months, but the success of treatment was much greater during the latter season. Complete fish kills were obtained in 97% of the 24 ponds treated during the summer, whereas only 72% of the 32 ponds treated during the fall resulted in the total elimination of fish populations.

The seasonal variation in the success of pond treatment is attributed to stagnation of the lower waters during the summer months. The seasonal occurrence of thermal stratification is manifest in the majority of Kentucky farm ponds and apparently has little effect on rotenone penetration, but the success of treatment was greatly enhanced by stagnation of the deep waters.

Effective rotenone penetration was from 5 to 8 feet in the ponds treated during the summer but a marked decrease in dissolved oxygen below these depths prevented fish from retreating into the lower waters to escape the toxicant. The maximum effective depth to which rotenone penetrated in the ponds treated during the fall did not exceed 7 feet in spite of the occurrence of complete circulation. High concentrations of dissolved oxygen in the lower waters provided a sanctuary for fishes that moved below the toxic zone.

In view of these findings, the treatment of fish populations in Kentucky farm ponds with a maximum depth greater than 7 feet should be restricted to the summer months, June through mid-September.

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