TABLE II

CATCH PER BASKET-DAY OF FISH TAKEN IN BASKETS FROM HIGH ROCK LAKE USING FISH SCRAPS AND COTTONSEED CAKE AS BAIT DURING THE PERIOD 11/22/57-11/23/58

	Fish Scraps		*Cottonseed Cake*	
Species	*Number*	*Weight*	*Number*	*Weight*
Catfish	3.986	1.170	8.172	1.135
Carp	0.010	0.009	0.401	0.405
Crappie	0.287	0.025	0.630	0.051
Sunfish	0.017	0.001	0.041	0.002
Others	0.007	0.003	0.003	0.002
TOTAL	4.307	1.208	9.247	1.595

caught more game fish than baskets baited with fish scraps, neither bait took fish in a manner that was deleterious to the reservoir fishery.

CONCLUSIONS

1. The total weight of catfish caught in baskets baited with cottonseed cake is not materially different from the total weight caught in baskets with fish scraps.
2. Catfish caught in fish-baited baskets averaged about twice the weight of those caught in cake-baited baskets.
3. Cottonseed cake-baited baskets took a considerable number of carp while the carp catch in fish-baited baskets is negligible.
4. Baskets baited with cottonseed cake took about twice as many game fish as baskets baited with fish scraps. The total game fish catch, however, was so small as to be considered harmless to the population.

COMPARATIVE TOXICITY TO BLUEGILL SUNFISH OF GRANULAR AND LIQUID HERBICIDES

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ABSTRACT

The toxicity to bluegill sunfish, *Lepomis macrochirus,* Rafinesque, of granular formulations of ten commercial herbicides is presented. The following chemicals are included: three esters of 2,4-dichlorophenoxyacetic acid; potassium salt of 2-(2,4,5-trichlorophenoxy) propionic acid; disodium salt of 3,6-endoxohexahydrophthalic acid; a mixture of the latter two materials; 2,3,6-trichlorophenylacetic acid; 2-methoxy-3,6-dichlorobenzoic acid; isopropyl n-(3-chlorophenyl) carbamate; and 2,6-dichlorobenzonitrile. The difference in the median tolerance limit of bluegill sunfish to liquid and granular formulations is discussed. Of the ten herbicides tested, most proved less toxic as granular formulations than as liquid formulations. The difference in toxicity as affected by granule size and type is also discussed.

INTRODUCTION

These data are presented as an aid to aquatic biologists in determining the proper herbicides for use on vegetation where a fish kill is undesirable. It further annotates the difference between commercial herbicides as liquid and granular formulations.

The following herbicides are included in this discussion: isooctyl ester, propylene glycol butyl ether esters, and butoxy ethanol ester of 2,4-dichlorophenoxyacetic acid (2,4-D); potassium salt of 2-(2,4,5-trichlorophenoxy) propionic acid (silvex); sodium salt of 2,3,6-trichlorophenylacetic acid (fenac); disodium salt of 3,6-endoxohexahydrophthalic acid (endothal); a mixture of potassium salt of silvex and disodium salt of endothal; 2-methoxy-3,6-dichlorobenzoic acid (Banvel D); isopropyl n-(3-chlorophenyl) carbamate (CIPC); and 2,6-dichlorobenzonitrile (dichlobenil).

MATERIALS AND METHODS

Modifications of the biological assay techniques as outlined by Doudoroff *et al.* (1951) have been previously presented by Hughes and Davis (1963).

The effect of water quality on the median tolerance limit (Tl_m) of bluegill sunfish to herbicides is well documented (Davis and Hardcastle, 1959, and Surber and Pickering, 1962). The relatively uniform water quality of Bayou DeSiard, a quiescent lake near Monroe, Louisiana, makes it well suited for use as a dilution water. Average water analyses for 1957-1962 are presented in Table I. These analyses were conducted in the laboratory at intervals during the study.

TABLE I

ANALYSES OF WATER FROM BAYOU DESIARD, 1957-1962

Determination	*Mean**	*Range*
Hardness, ppm	29.0	17.0- 34.0
pH	6.9	6.5- 7.4
Alkalinity, ppm as $CaCO_3$	40.0	9.0-100.0
Turbidity, ppm	32.0	9.0- 70.0
Dissolved oxygen, ppm	5.0	4.0- 8.0
	Dissolved solids, ppm	
Copper	0.1	T†- 0.3
Iron	0.6	0.2- 2.9
Aluminum	0.5	0.0- 3.1
Sulfate	12.1	9.0- 21.0
Chromate	0.1	0.1- 0.2
Nitrite	T†	T†- 0.1
Nitrate	T†	T†- 0.1
Phosphate	0.3	0.1- 0.4
Chloride	6.1	0.6- 20.0
Tannins and lignins	0.9	0.6- 1.4

* Average of weekly analyses. † Less than 0.05 ppm.

RESULTS AND DISCUSSION

2,4-D

The bioassay results of various 2,4-D formulations are found in Table II. The toxicity of the liquid isooctyl ester to bluegill sunfish varies widely among commercial formulations (Hughes and Davis, 1963). For this reason each company's liquid material was compared with its granular counterpart. Without exception, the granular 2,4-D materials were much less toxic than the liquid material. On the basis of these findings it is apparent that the likelihood of a fish kill is greatly reduced when granular 2,4-D materials are used. One company stated that the difference between their liquid 2,4-D formulation and the granular 2,4-D formulation was the presence of additives, surfactants, and oils in the liquid material. The granular formulations were made by impregnating the unformulated ester directly on the attaclay.

The effects of the loss of a highly volatile chemical from the attaclay granules has been a topic of much discussion. Using the butoxy ethanol ester, studies were conducted using granules which had been exposed to the open air and granules which had remained in a closed container. The results as presented in Table II, indicate that the granules in the closed container were much more toxic. This is probably due to a greater retention of the ester by the granules in the closed container. If the ester is lost when the shipping bag is left open, it seems reasonable to assume that the herbicide will fail to perform as expected. This should be considered when planning field applications.

The effect of granule size upon the release of a herbicide into the water column should be studied further. Observations taken during the bioassay studies indicate that the smaller granules tend to release a herbicide more rapidly. The very large granules required 48 hours or longer to build up the concentration most lethal to fish. Wilkinson, 1962, found that the amounts of herbicide recovered from granules was directly associated with decreasing

TABLE II

MEDIAN TOLERANCE LIMIT OF BLUEGILL SUNFISH TO COMMERCIAL HERBICIDES

	Tl_m in ppm Acid Equivalent			
	Liquid Formulation		*Granular Formulation*	
Herbicide	*24 hr.*	*48 hr.*	*24 hr.*	*48 hr.*
2,4-D isooctyl ester	8.8	8.8	133.0	116.0
2,4-D isooctyl ester	24.0	23.0	215.0	209.0
2,4-D isooctyl ester	66.3	59.7	over 1,000.0	over 1,000.0
2,4-D propylene glycol butyl ether ester	2.1	2.1	9.3	9.3
2,4-D butoxy ethanol ester	2.1	2.1	36.5* 43.4†	34.5* 41.4†
Silvex, Potassium salt	83.0	83.0	100.0	100.0
Fenac	22.5	22.5	20.0	15.0
Endothal	450.0	280.0	650.0	280.0
Endothal and silvex	500.0	400.0	1,000.0	600.0
Banvel D	600.0	410.0	20.0‡ 67.5§	20.0‡ 67.5§
CIPC	20.0	12.0	10.0	8.0
Dichlobenil	17.0¶	17.0¶	37.0	30.0

* Stored in closed container. † Stored in open container. ‡ On vermiculite granules.
§ On attapulgite granules. ¶ Wettable powder.

granule size, rising temperature, and length of time of exposure to the receiving water.

The use of the various esters of 2,4-D in liquid formulations for emergent aquatic vegetation has been widely recommended (Surber, 1961). The toxicity of the liquid 2,4-D esters as commercially formulated is too high for the materials to be indiscriminately applied to aquatic habitats. If liquid 2,4-D is preferred the less toxic amine formulations should be considered (Hughes and Davis, 1963). The granular 2,4-D esters are generally less toxic than the liquid esters. The granular formulation of propylene glycol butyl ether ester, of those tested, is not recommended for aquatic application. The other four granular formations can safely be used, if label recommendations as to rates are followed.

Silvex

Silvex has been recommended for use on many submersed weeds (Younger, 1958; Surber, 1961; and Bennett, 1962). Field application recommendations vary from 1 to 5 ppm depending upon the control desired. This offers a wide margin of safety as the Tl_m for potassium silvex was established at 83 ppm in moderately hard water (Hughes and Davis, 1963). Surber and Pickering, 1962, found that potassium silvex pellets in their hard water gave a Tl_m of 120 ppm and 91 ppm for 24 and 48 hours, respectively. The same investigators derived a Tl_m of 21 and 15 ppm in soft water for the same periods. The difference in toxicity to bluegill between the liquid and granular formulations of potassium silvex is insufficient to necessitate separate recommendations for field applications.

Fenac

Fenac is used in preemergence applications for the control of *Potomogeton* sp. in the midwest on bottom areas where water has been drained off.[1] In Louisiana fenac is still being evaluated. Stamper and Thornton, 1962, found that the material was well adapted for the control of Johnson grass in sugarcane. Its use on aquatic plants will probably be as a herbistat and for a preemergent on mud flats and drawn down areas. The present trial application rates are from 5 to 40 pounds per acre which allows an adequate safety margin for fish toxicity. The liquid formulation tested, a sodium salt, registered a Tl_m for bluegill sunfish of 22.5 ppm while a granular formulation of the same herbicide resulted in a Tl_m of 20 ppm for bluegill sunfish (Hughes and Davis, 1962).

Endothal

The disodium salt of endothal has received wide acceptance for application on submersed aquatic vegetation. Application recommendations vary from 1

[1] Personal communication, 1962. John E. Gallagher, Amchem Products, Ambler, Penn.

to 5 ppm active ingredient. This provides a wide safety margin between toxicity to plants and toxicity to fish.

The granular endothal on 8/15 mesh attaclay carrier was less toxic than the liquid material at the end of 24 hours. This was apparently due to the time required for the herbicide to be released from the granules. At the end of 48 hours the liquid and granular material gave comparable results with each recording a Tl_m for bluegill sunfish at 280 ppm. Disodium endothal has been found to develop maximum toxicity at the 96 hour exposure level. Our investigations revealed a Tl_m of 200 ppm for 96 hours. This agrees in essence with the findings of Walker, 1962, when he reported 125-150 ppm under varying water temperatures.

Endothal and Silvex

The combination of disodium endothal and potassium silvex has received study for certain hard to kill aquatics (Houser and Gaylor, 1962). On the basis of field studies, this combination will be commercially available in 1963.[2] Our studies indicate that the combination at comparable concentrations is less toxic to fish than either of its active components. No explanation of this is readily available.

Once again the pelletized material was less toxic than the liquid. At the completion of the 48 hour test, the granules were 30% less toxic than the liquid.

Banvel D

Banvel D is an experimental material which has shown promise as a broad spectrum herbicide on terrestrial weeds according to information received from the formulating company. Recently it has been tested in Louisiana as a possible control for alligator weed, *Alternanthera philoxeroides*. Field applications to aquatics are expected to be in the 5 to 10 ppm range.

The dimethylamine salt was tested as a liquid formulation and was found to be relatively nontoxic to fish. The granular formulations of Banvel D were much more toxic than the dimethylamine salt. Information from the formulator indicates that a solvent is added to the technical acid which is then sprayed on the carrier vermiculite or attapulgite to obtain the granular formulations. It would appear that the addition of this particular solvent is responsible for the increase in fish toxicity of the granular material.

CIPC

This material has not as yet received extensive use as an aquatic herbicide. Its use as a granular formulation on a 15/30 mesh attaclay carrier did little to make it more acceptable. As a liquid it gave a median tolerance limit of 20 ppm while as a granular formulation a 10 ppm Tl_m for bluegill sunfish was determined. These toxicity values fall in the general range reported by Applegate *et al.* (1957). More testing should be given this material before planning field applications due to the narrow safety margin between anticipated field application rate and median tolerance limits.

Dichlobenil

Since development of this material in the Netherlands prior to 1960, it has received extensive testing both as a preemergent on terrestrial weeds and as a growth regulator on aquatic weeds. At present it is being tested in combination with phenoxy compounds for use on alligator weed. The wettable powder formulation mixes quite well with emulsified herbicides. Its use will probably not be limited due to fish toxicity as the Tl_m of 17 ppm is well in excess of the trial concentrations presently being investigated. As a granular herbicide its 48 hour Tl_m for bluegill sunfish of 30 ppm makes it acceptable as a possible preemergence herbicide on drawn down impoundments.

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2 Personal communication, 1962. W. Harry Culver, Pennsalt Chemicals, Bryan, Texas.

Midland, Michigan; Hercules Powder Company, Wilmington, Delaware; Niagara Division of Food, Machinery, and Chemical Corp., Jackson, Mississippi; Pennsalt Chemicals Corp., Tacoma, Washington; and Velsicol Chemical Corp., Chicago, Illinois.

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TEMPERATURE PREFERENCES BY TWO SPECIES OF FISH AND THE INFLUENCE OF TEMPERATURE ON FISH DISTRIBUTION [1]

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ABSTRACT

Experiments were conducted to determine the preferred temperatures and the final preferenda of *Pimephales promelas* and *Lepomis cyanellus*. Specimens of *P. promelas* and *L. cyanellus* were acclimated to five and four different temperatures for 30 days. A gradient tank was built permitting a temperature gradient of 2° C. per chamber. Openings in the partitions between the chambers let the fish move freely throughout the tank. One fish was used to a test and ten tests for each acclimation level. Recordings of the position of each fish were made every 15 seconds for 40 minutes. The temperatures corresponding to the modes were averaged to obtain the preferred temperature for the acclimation level. *Pimephales promelas* and *L. cyanellus* acclimated rapidly to high temperatures but required about two weeks

[1] Contribution No. 355 from the Department of Zoology, Oklahoma State University.