Survival of walleyes from eggs of known DDT and dieldrin residues in three southeastern Wisconsin lakes : progress report. No. 21 1967

Kleinert, Stanton J.
[Madison, Wis.]: Wisconsin Conservation Dept., Research and Planning Division, 1967

Research Report No. 21
(Fisheries)

SURVIVAL OF WALLEYES FROM EGGS OF KNOWN DDT AND DIELDRIN RESIDUES IN THREE SOUTHEASTERN WISCONSIN LAKES

Progress Report

By

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March, 1967

ACKNOWLEDGMENTS

Grateful acknowledgment is made to Howard Wenzel of the Fish Management Division for spawning the walleyes after they were netted; Paul Degurse, Conservation Department fish pathologist for conducting fat and water analyses and preparing samples for pesticide analysis; to the Wisconsin Department of Agriculture pesticide laboratory under the direction of R. J. Moubry for conducting the pesticide analyses; and to Lyle M. Christenson and C. Kabat for critical review of the report.

Edited by Ruth L. Hine

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INTRODUCTION

Background

Whole fish samples from 31 Wisconsin waters were analyzed by gas chromatography for DDT and Dieldrin residues in 1965. All of the fish analyzed contained DDT and most contained measurable amounts of Dieldrin (Thompson, 1966). Distinct differences in DDT residue levels in fish from different waters were noted. Dieldrin residues in fish were present in much smaller amounts and showed less variation from one body of water to another. The highest DDT levels observed in the survey were found in fish taken at Lake LaBelle, Waukesha County, the only southeastern Wisconsin lake sampled. Here total DDT, measured as ppm in the fat, ranged from 57.2 for walleyes to 242.5 for yellow perch.

These data prompted concern over the possible effects of pesticide residues, particularly DDT, on the fisheries resource. Thus a broadened research program was undertaken in 1966. Objectives were to expand the survey begun in 1965 and to investigate fish reproduction in lakes known to have fish of high pesticide residue level.

Fishery research investigations since 1958 had shown poor natural reproduction of walleyes in Lakes LaBelle and Golden, Waukesha County; stockings were required to maintain a fishery for the species. In contrast, Pike Lake, Washington County, had shown excellent walleye natural reproduction. These three lakes were consequently chosen for comparison of walleye reproductive success with pesticide residues in the eggs in the spring of 1966.

Previous attempts to associate DDT with reproductive failures of fish were made by Burdick et al. (1964) and Allison et al. (1964). Burdick et al. showed that a DDT concentration in the ether extract of lake trout fry equivalent to 2.9 ppm or above in the weight of the fry resulted in mortality. The mortality syndrome appeared after absorption of the yolk sac when the fry were about ready to feed. Allison et al. found a critical period shortly after hatching when mortality was noticeably higher in the offspring of cutthroat trout exposed to high DDT concentrations. The residue data for the eggs and fry showed that appreciable amounts of chlorinated hydrocarbons were passed along by the parent fish and, in general, higher residues were found in eggs of fish receiving higher dosages of DDT.

Description of the Study Areas

Lake LaBelle lies between the other two study lakes, 8 miles north of Golden Lake and 18 miles southeast of Pike Lake. Lakes LaBelle and Pike are natural drainage lakes kept at constant levels by dams located at the outlets. Golden Lake is an intermittent natural drainage lake, having an outflow only during periods of high water. The lakes differ in size, but are similar in chemical characteristics, all being hard water lakes typical of the region (Table 1).

Bluegill and largemouth bass provide a large share of the sport fishery in LaBelle and Golden Lakes, while perch and walleye are the principal species caught by fishermen in Pike Lake. All three lakes have some gravel shoals where walleyes are known to spawn.

The three lakes differ in terms of human habitation in the watershed. Homes utilize about 50 percent of the shoreline of Golden and Pike Lakes; the remainder of the shoreline is undeveloped farmland or marsh. The shoreline of LaBelle is totally developed into homes or instutional properties; the lake basin, bordering the City of Oconomowoc, lies in a more densely populated region than occurs in the immediate vicinity of Golden and Pike Lakes.

MATERIALS AND METHODS

Fieldwork and Fish Culture

Fyke nets were set at the three lakes within two weeks of the spring ice melt. The nets were fished until a sufficient number of walleyes were spawned or until the spawning run was over.

Walleyes were spawned by the wet method. Milt from the male was extruded into a plastic pan containing one-half inch of water by gently squeezing the sides of the fish. Eggs from a ripe female were immediately added to the pan by stroking the female from head to vent. Milt from a second male was then added to the pan to insure fertilization. The eggs, milt, and water were then added to a plastic pail containing water and bentonite (a fine clay). The eggs were mixed by hand and allowed to water-harden for 20 minutes. Each female and its eggs were then marked with a numbered tag and returned to the Delafield hatchery.

At the hatchery, each lot of eggs was stirred by hand again to break any clumps that may have developed and then placed in Downing hatching jars. The eggs in each jar were counted within 24 hours of placement in the jars and again when the eyed stage was reached. Egg counts were made by enumerating the number of eggs in a 1 cc sample to include the total volume of the eggs. Throughout the hatching period, water flow was monitored to insure a steady but gentle roll of the eggs; dead eggs were removed as they appeared and the temperature of the hatching battery water from Lake Nagawicka was continually recorded.

Each jar flowed into a separate 1-1/2 by 2-foot cylindrical screen enclosure in the raceway below. Swim-out fry were collected in the screens. The screen enclosures proved to be the principal weakness of the experimental gear, as fry could not be held in the screens more than a few hours without mortality. The percentage of living to dead fry in the screens was determined by averaging the percentages of live fry found in a total of six dipper samples from each screen taken over the hatching period. Two samples of 200 fry were removed from each screen and stocked into 20-gallon laboratory aquaria and 100-gallon muslin enclosures in Delafield Pond IV. Counts of the survivors of these stockings were made when the yolk had been absorbed and the young fish were ready to feed.

In the fall, each of the three lakes was boomshocked to see if walleye young had been produced in 1966. The boomshocking gear consisted of a three-phase, 230-volt A.C. unit, carried on an outboard motor-driven boat, equipped with three electrodes suspended in triangular fashion. The surveys circuited the shoreline of each lake to a depth of 6 feet.

Sample Preparation and Laboratory Analysis

Following spawning, female walleyes were wrapped tightly in aluminum foil and frozen. Egg samples were collected in aluminum foil-covered glass jars and frozen at the time the eggs were placed in the hatching jars.

Fat and water analyses were conducted on the walleye females and samples prepared for pesticide analysis; each frozen fish was ground whole in a meat grinder and thoroughly mixed prior to the selection of the sample. The Wisconsin Department of Agriculture pesticide laboratory conducted the fat and water analyses of the eggs and determined the pesticide residues in all egg and fish samples prepared in this study.

The analytical procedures used were those described for animal tissues and for eggs in Pesticides Analytical Manual Vol. I (Revised July, 1965), U. S. Department of Health, Education and Welfare. Pesticide residue levels were determined by electron capture gas chromatography (Jarrell-Ash Models 28-710 and 28-730), utilizing a mixed bed column, 4 m.m. i.d. by 6 feet glass, packed with nine parts 10 percent DC200 on gas chrom Q and five parts 10 percent QFL on gas chrom Q, 60-80 mesh. The column temperature was 205°C., and the flow rate was 60 m.l. N_2/min. The detector of this equipment was used with a temperature of 210°C. and a voltage of 18 v., the injector temperature being 232°C.

The laboratory reported residues as total DDT analogs, DDT, DDD, DDE, and Dieldrin in ppm on a "fat basis" for the females and on a "whole (wet) basis" for the eggs. Conversions have been made to express residues on a fat and a whole fish basis in both fish and egg samples. These conversions have been accomplished by projecting the amount of pesticide contained in the fat to include the whole fish and the reverse for the eggs. However, Dieldrin residues in the eggs are left expressed on a whole (wet) basis only as insufficient residues were present to allow a meaningful reconversion to the fat basis.

FINDINGS

Net Catches During the Spring Spawning Run

Catches of walleyes during the spring spawning run, April 3-19, reflected a distinct difference in walleye abundance in the three lakes (Table 2). The number of walleyes caught per net day of effort amounted to 29.7 at Pike Lake, 7.9 at Lake LaBelle, and 3.8 at Golden Lake.

Eight ripe females were obtained for spawning at Pike Lake in one night of netting, 4 ripe females in 15 nights of netting at Lake LaBelle, and 4 ripe females in 12 nights of netting at Golden Lake.

Over the netting period, recorded water temperatures ranged from 40° to 51°F. The first appearance of ripe females was associated with water temperatures of 47°F. or above.

Fish Culture

Spawn was taken from walleyes at the three lakes between April 15 and 19. Samples of at least 30 grams of eggs were taken from each fish for pesticide analysis. There remained a sufficient number of eggs from 15 of the 16 females to be held and observed in separate hatching jars at the Delafield Station (Table 2).

Clumping and fungusing of the eggs shortly after placement in the hatching battery accounted for a 90 percent mortality of the eggs from one Lake LaBelle female and a total mortality of eggs from one Golden Lake female (Table 3). Eggs from the remaining females averaged 66.9 percent survival to the eyed stage.

Between the eyed stage and hatching, eggs from 5 of 6 females from Lakes LaBelle and Golden, and 1 of 8 females from Pike Lake, suffered an almost total mortality. This mortality was evident by the observation of dead fry and dead eggs in the jars and by the low percentage of live fry in the collecting screens.

Hatchery water temperatures over the period of incubation ranged from 40-50°F. and averaged about 48.2°F. The water was frequently turbid due to silt and algae and the hatching equipment required frequent cleaning. A sample of hatchery water was taken on April 21. Analysis showed the hatchery water supply to be high in nitrates and phosphates, exceeding similar measures made on water samples taken from the three study lakes on the same date (Table 1).

Survival of Fry

Survival of fry to the feeding stage in aquariums ranged from 32.5 to 97.0 percent and averaged 63.1 percent. Survival of fry in muslin baskets over the same period ranged from 2.0 to 25.0 percent and averaged 13.5 percent. In the aquariums, dead fry were detected soon after placement and were believed to have died from handling. The poor survival of fry in the muslin baskets may have been due to one or more of a number of factors, including toxicity of basket frame paint, or muslin laundering detergent or chemical or temperature conditions within the pond where the baskets were located. The fry survival studies did not indicate better survival from one lake than from another.

Pesticide Residues in Fish and Eggs

Pesticide residues expressed on the whole (wet) basis in both fish and eggs are a function of the amount of pesticide residue in the fat and the amount of fat present. Fat content of females varied from .73 to 5.54 percent, while fat content of eggs varied from 1.94 to 3.70 percent. Some females and eggs with high residue levels of pesticides in the fat were found to be low in total pesticide residues due to a low fat content (Table 3).

Water content of females varied from 71.93 to 77.10 percent, while water content of eggs varied from 86.29 to 91.00 percent. The water content of the eggs may have been biased by the degree of water hardness of the eggs at sampling and the presence of water in some sample bottles.

Distinct differences in DDT residues in fish and eggs from the three lakes were evident. Total DDT residues in the fat of females and eggs averaged 161.1 and 119.0, 34.3 and 44.0, 13.1 and 11.1 ppm at Lakes LaBelle, Golden, and Pike, respectively. A correlation coefficient of .91 was calculated for the total DDT residues in the fat of females and the fat of their eggs (.001 significance with 14 d.f.), indicating a very high degree of association between DDT residue levels in brook fish and their eggs. At each lake there was little or no association between fish length and total DDT expressed on the fat basis.

In the females, DDE, DDD, and DDT constituted about 38, 23 and 39 percent of the total DDT complex. In the eggs, DDE, DDD, and DDT constituted about 41, 23, and 36 percent of the total DDT complex. The representative percentages of the DDT residue components in the fish and eggs were generally consistent in the samples and did not appear to be related to either the lake sampled or the length of the females.

Dieldrin residues in the fish and eggs from the three lakes were nearly identical. Dieldrin residues in the fat of females averaged .32, .37, and .32 ppm at Lakes LaBelle, Golden, and Pike. There was no association between fish length and Dieldrin concentration in the fat. Dieldrin residues were either undetected, present in trace amounts, or were present in very small amounts in the egg samples.

Sources of Pesticide Residues in Fish and Eggs

It is difficult to determine the amounts of pesticides applied to the watersheds of these three lakes, as no single group or agency can be identified as the principal user. The source of pesticides accumulating in the fish is theorized to originate from pesticide usage chiefly by local property owners for garden pests, mosquito control and control of elm bark beetles, the carriers of Dutch elm disease. Consistent with this theory Lake LaBelle, located in the most urbanized watershed, had walleyes and eggs with the greatest DDT concentrations.

Pesticide Residue - Walleye Reproductive Failure Relationship

A critical period of mortality was detected during the hatching and fry developmental stages. This critical period occurred just prior to hatching, resulted in an almost total mortality of eggs, and was most frequent among eggs from Lakes LaBelle and Golden, where walleye reproduction is poor and where the highest DDT residues in the fat of walleye eggs was observed. Contrary to this general finding, many eggs from one Lake LaBelle lot containing 150 ppm total DDT in the fat (the highest residue level observed in the eggs) survived, while most eggs from a Pike Lake lot containing 13.6 ppm total DDT in the fat (one of the lower residue levels observed) perished at hatching. While these data alone do not warrant a positive conclusion, a relationship worthy of further study was revealed. However, a second study involving many more fish, an improved water supply and improved experimental gear is needed.

Dieldrin may not be associated with the egg mortalities, since only a few lots of eggs contained measurable amounts of Dieldrin and little difference in Dieldrin levels of egg samples was apparent between the three lakes.

Fall Electrofishing Surveys

Night electrofishing surveys were conducted at Lake LaBelle (September 21 and 26), Golden Lake (September 8 and 27), and Pike Lake (October 19). Catches of young-of-the-year walleyes per hour of electrofishing amounted to .5 at Lake LaBelle, 0 at Golden Lake, and 11.6 at Pike Lake. These findings were consistent with surveys taken in recent years which showed that Lakes LaBelle and Golden had produced few walleyes, and Pike Lake had produced a walleye year class, although the young-of-the-year were not as abundant at Pike Lake as in former fall surveys.

CONCLUSION

The first year's effort served to acquaint us with many of the problems associated with a study of this nature. The principal problem, obtaining walleye spawn, is associated with many factors beyond our control -- the walleye spawning period may be brief, the number of females small, and windy weather adverse to lifting nets. The remaining problems lie within our control and procedures will be improved when this study is repeated: better collection of egg samples to insure uniform water hardness; good hatchery water quality; more detailed observation of eggs and fry; and a better method of retaining swim-up fry.

These studies indicate a possible association between DDT levels in the eggs and mortality. However, many more trials will be needed before this association can be firmly established or disproven. Future studies should involve a larger sample of walleyes from a number of Wisconsin lakes.

LITERATURE CITED

Allison, D., and B. J. Kallman, O. B. Cope and C. Van Valin.
1964. Some chronic effects of DDT on cutthroat trout. U. S. Fish and Wildlife Serv. Research Report 64, 30 p.

Burdick, G. E., E. J. Harris, H. J. Dean, T. M. Walker, J. Skea, and D. Colby.
1964. The accumulation of DDT in Lake Trout and the effect on reproduction. Trans. Amer. Fish. Soc. 93(2):127-136.

Thompson, D. R.
1966. Pesticide residues in Wisconsin fish. Wis. Conserv. Dept. Survey Report, 9 p. (mimeo).

TABLE 1

Physical and Chemical Characteristics of Lakes LaBelle, Golden, Pike and Nagawicka

Measurement	LaBelle	Golden	Pike	Nagawicka*
Physical Characteristics				
Surface acres	1,117	250	522	957
Miles of shoreline	8.7	3.4	3.8	8.6
Maximum depth in feet	46	46	45	90
Chemical Characteristics**				
Methyl Orange Alkalinity	186	185	189	248
pH	8.7	8.9	8.55	8.5
Cl^-	9.0	7.5	8.0	9.5
Na^+	4.30	4.30	4.00	5.00
K^+	1.95	2.75	2.00	2.08
Ca^{++}	38.4	33.3	49.7	43.1
Mg^{++}	29.9	26.7	45.7	34.0
Zn^{++}	.004	.004	.005	.004
Cu^{++}	.003	.002	.002	.002
Fe^{++}	.04	.07	.04	.04
NO_3-N	.16	.06	.06	.26
PO_4(D)	.216	.063	.033	.356
PO_4(T)	.265	.070	.075	.375

* Sample taken from lake water flowing through the hatchery.

** Units are ppm with the exception of pH. All samples were taken one foot below the surface on April 21, 1966.

TABLE 2

Fate of Eggs and Fry From Walleye Females From Lakes LaBelle, Golden, and Pike

Lake	Spawning Females		Total DDT Analogs ppm in fat		Survival Percentages			
	Length in Inches	Weight in Pounds	Fish	Eggs	Eggs Reaching the Eyed Stage	Live Fry in Screens	Live Fry Reaching the Feeding Stage	
							Aquariums	Baskets
LaBelle	15.4	1.1	99.80	107.2	83.3	.5	-	-
LaBelle	19.2	2.7	151.5	111.8	63.3	0	-	-
LaBelle	19.3	2.35	207.9	106.7	9.1*	0	-	-
LaBelle	23.6	4.4	185.0	150.2	92.8	19.7	32.5	25.0
Golden	17.9	1.65	33.90	26.86	0*	-	-	-
Golden	23.2	3.8	34.99	45.96	-**	-	-	-
Golden	24.0	4.5	48.20	35.63	93.8	1.0	80.0	25.0
Golden	27.5	6.9	20.12	67.62	85.3	2.0	65.0	1.7
Pike	15.5	1.4	19.48	8.05	51.2	20.9	55.0	10.5
Pike	16.3	1.45	9.77	13.61	40.9	.5	-	-
Pike	16.4	1.45	15.02	12.81	37.5	31.2	-	-
Pike	16.8	1.65	12.95	10.09	75.4	66.5	84.5	15.5
Pike	17.0	1.8	13.60	17.53	43.6	69.2	39.5	2.5
Pike	17.1	1.8	10.26	8.87	62.8	54.9	48.0	36.0
Pike	18.0	2.45	10.78	8.75	65.7	85.8	97.0	2.0
Pike	19.6	1.75	12.90	9.08	73.7	76.6	66.0	3.5

* Eggs clumped and fungused.

** Insufficient number of eggs to run in a hatching jar.

TABLE 3

Water, Fat, and Pesticide Analysis for Walleye Females and Their Eggs From Lakes LaBelle, Golden, and Pike

Walleye Females									Walleye Roe						
				Whole Fish Basis - ppm							Whole Egg Basis - ppm				
Length in Inches	Weight in Pounds	Percent Water	Percent Fat	DDE	DDD	DDT	Total DDT Analogs	Dieldrin	Percent Water	Percent Fat	DDE	DDD	DDT	Total DDT Analogs	Dieldrin
							Lake LaBelle								
15.4	1.1	73.98	5.49	3.02	1.25	1.21	5.48	.024	90.93	2.35	.993	.566	.960	2.52	-
19.2	2.7	73.20	4.04	2.30	1.54	2.28	6.12	.017	91.00	2.12	.806	.715	.854	2.37	Trace
19.3	2.35	73.27	3.61	2.65	1.74	3.12	7.51	.009	86.29	3.12	1.00	.98	1.35	3.33	-
23.6	4.4	72.96	4.12	3.06	1.65	2.91	7.62	.008	90.61	2.21	1.06	.95	1.31	3.32	-
							Golden Lake								
17.9	1.65	73.32	3.83	.53	.34	.42	1.29	.002	90.10	2.55	.277	.191	.217	.685	-
23.2	3.8	75.45	1.76	.28	.13	.20	.61	.001	88.76	2.35	.410	.298	.372	1.08	-
24.0	4.5	72.30	5.00	1.04	.53	.85	2.42	.021	90.40	2.13	.312	.173	.274	.759	.005
27.5	6.9	77.10	.73	.02	.04	.08	.14	.0002	90.74	2.10	.721	.288	.412	1.42	-
							Pike Lake								
15.5	1.4	74.46	4.80	.24	.31	.39	.94	.017	87.48	3.70	.126	.063	.124	.313	Trace
16.3	1.45	73.53	4.15	.16	.09	.16	.41	.014	87.48	2.66	.159	.082	.121	.362	Trace
16.4	1.45	75.29	2.61	.15	.07	.18	.40	.009	88.75	2.78	.65	.062	.129	.356	Trace
16.8	1.65	73.71	4.05	.21	.12	.19	.52	.013	86.50	3.48	.148	.073	.130	.351	-
17.0	1.8	74.14	4.13	.20	.13	.23	.56	.009	90.50	1.94	.162	.062	.116	.340	Trace
17.1	1.8	73.68	5.12	.21	.10	.21	.52	.016	88.04	3.28	.126	.063	.102	.291	.006
18.0	2.45	71.93	5.54	.22	.13	.24	.59	.015	87.42	2.97	.102	.065	.093	.260	-
19.6	1.75	72.11	3.62	.17	.10	.20	.47	.013	89.87	2.71	.101	.049	.096	.246	Trace

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