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James W. Merna

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INTRODUCTION OF CHLORINATED HYDROCARBONS INTO STREAM FISHES BY SPAWNING SALMON[1]

By James W. Merna

Abstract

The extent of contamination with chlorinated hydrocarbons of trout resident in two small streams by spawning coho and chinook salmon was determined. An attempt was made to trace PCB, DDT, and dieldrin through the aquatic system following their release from decaying salmon carcasses.

No retention of contaminants within the food chain was found. Analysis of stream sediments and crayfish failed to reveal measurable concentrations. However, trout, and to a lesser extent sculpins, accumulated PCB and DDT as a result of eating contaminated salmon eggs. Eggs constituted as much as 87% (by weight) of the total stomach contents of trout collected during the salmon spawning season. The PCB level in salmon eggs ranged from 0.46 to 9.50 ppm, and they were found in trout stomachs from early October to early January. Thus the diet of trout carried a significant level of contamination for a period of at least 90 days. Utilization of eggs was highly variable among individual trout, and there was a strong correlation between numbers of eggs in the stomachs and PCB levels in the fillets. Concentrations of chlorinated hydrocarbons in trout fillets ranged from 0.20 to 4.63 ppm of PCB and 0.11 to 2.52 ppm of DDT. These materials were never detected in samples from the control stream.

[1] Contribution from Dingell-Johnson Project F-35-R, Michigan.

Introduction

Body tissues of salmonid fishes of the Great Lakes are known to contain several environmental contaminants, including polychlorinated biphenyl (PCB), mercury, dieldrin, and DDT. Fillets taken from salmon larger than 10 pounds, collected in Lake Michigan in 1977, contained PCB levels ranging from 1.46 to 26.18 ppm and DDT values of 0.75 to 13.10 ppm (Anonymous 1977).

The purpose of this study was to assess the extent of contamination of stream fish, and streams, from death and decay of salmon following spawning. It was reasoned that DDT and PCB would be released from decaying carcasses and adsorbed to organic silt in the streambed, where it would be available to enter the food chain.

Salmon carcasses tend to become buried in silt beds in quiet areas of spawning streams, where they remain until totally decomposed. These highly organic silt beds would have a high affinity for the released chlorinated hydrocarbons. It is also possible that the dead salmon would be eaten by crayfish, amphipods and other aquatic organisms, thus directly entering the food chain. Crayfish and amphipods tend to be general scavengers, feeding on freshly dead animals and plant and animal debris (Pennak 1953). Odum et al. (1969) reported DDT to have a high affinity for organic detritus. Fiddler crabs fed plant detritus containing 10.0 ppm DDT for 11 days experienced a threefold increase (0.24 ppm to 0.88 ppm) in muscle concentration. By the fifth day of the feeding experiment, all of the crabs had lost coordination.

PCB is structurally like DDT and seems to behave similarly in the environment. Both are known to be concentrated by fish directly from the water and through the food chain. Jarvinen et al. (1976) exposed fathead minnows to concentrations of DDT in the water and in the diet. Mean concentration factors were 1.2 times from the diet and 100,000 times from the water. Residues contributed by dietary DDT were additive to those from the water, and mortality was higher in fish exposed to both sources than in those exposed to either source alone.

Exposure of brook trout to a range of 0.01 to 0.94 ppb PCB (Aroclor 1254) resulted in tissue concentrations in direct proportion to the concentration in the water (Snarski et al. 1976). Tissue residues reached equilibrium levels after 14 weeks of exposure ranging from undectable (less than 0.2 ppm) to 2 ppm at the highest level of exposure. If release of PCB from dead salmon is sufficient to maintain a significant level in the waters of a spawning stream over an extended period of time, it is possible that resident trout would be subject to both direct uptake from the water as well as intake with food.

Methods

Field collections

Three Michigan trout streams were selected for this study. Two of the streams were known to have extensive salmon spawning runs of both coho (*Oncorhynchus kisutch*) and chinook salmon (*Oncorhynchus tshawytscha*). The third stream is not accessible to anadromous fish and, thus, it served as a control stream. The spawning streams were Bigelow Creek, Newaygo County (a tributary of the Muskegon River), and Pine Creek, Manistee County (a tributary of the Manistee River). The control stream was Hersey Creek, Osceola County (a tributary of the Muskegon River). Migrating fish are blocked from this creek by Croton Dam on the Muskegon River.

The three streams were chosen because they were: (1) in similar land-use areas, (2) similar in size and flow, and (3) isolated from industrial and urban contamination. All three streams also contained at least one trout species in common--the brown trout (*Salmo trutta*).

The streams were sampled periodically between October 13, 1977, and December 7, 1978. This period of time was sufficient to include two complete salmon spawning runs. Salmon start entering the streams in late September, and spawning continues through December.

Parameters sampled were chosen in order to represent, as nearly as possible, all levels of the food chain. Stream sediments, sculpins, and brown trout were collected each time the streams were visited. Mottled sculpins (*Cottus bairdi*) were collected in Bigelow Creek, and slimy sculpins (*Cottus cognatus*) were found in Pine Creek.

Rainbow trout (Salmo gairdneri) were collected in Pine and Bigelow creeks, however, it is recognized that their migratory habits make it difficult to determine the origin of any tissue contaminants. Rainbow trout are not present in Hersey Creek.

All trout were measured, stomachs were removed, and scale samples taken at the streams. Stomachs were immediately preserved in 10% formalin solution to stop digestion. All trout, stomachs, and scale samples were numbered individually for later identification. Sculpins were preserved intact in formalin.

An age-size distribution was determined from trout collected the first time the streams were sampled. On subsequent sampling trips, an attempt was made to collect six each of ages I and II brown trout and age I rainbow trout. Because of variability of sizes within age groups, this was not always accomplished. Brown trout are not abundant in either Pine Creek or Bigelow Creek, and consequently, an attempt was made to keep the total number of trout sacrificed at a minimum.

Adult coho and chinook salmon were collected periodically during spawning runs. Edible fillets and eggs were retained for contaminant analysis.

All samples, except the preserved stomachs and sculpins, were kept on ice until returned to the laboratory where they were frozen until they could be prepared for analysis.

An attempt was made to sample a benthic invertebrate species, however, no one bottom organism could consistently be found, in each of the three streams, in sufficient quantity for tissue analysis. Crayfish, which are susceptible to electrofishing, were found only in Bigelow Creek and were never abundant.

Stream sediments were sampled from all three streams. Two areas were selected as sampling stations in each stream. The areas were selected with the intent of one station having a high organic silt content, and the other being almost pure sand.

A core sampler for collecting sediments was made by cutting the bottom out of a polyethylene 50-ml graduated cylinder. A sediment sample consisted of five cores taken at each sampling station. The cores were collected by pushing the sampler into the sediment to the 50-ml mark on the cylinder. A sample thus consisted of five 50-ml sub-samples which were thoroughly mixed in a plastic bag. Sediments were kept on ice until returned to the laboratory, where they were frozen until analyzed.

Laboratory methods

Trout and sculpin stomachs that were preserved at the streams were returned to the laboratory, where major food items were enumerated. During the 1977 salmon spawning period, it became obvious that salmon eggs constituted a high percentage of the diet of the stream fish. Because of the large size of salmon eggs, relative to most other food items, it was obvious that numerical analysis of stomach contents did not represent the significance of the various items in the diet. Consequently, during the 1978 spawning run, the weight of salmon eggs was separated from the total weight of the remaining stomach contents. The items were weighed on an electric balance after being brought to a uniform state of dryness. Excess moisture was removed from the items by placing them in a small, fine-mesh, wire basket, made to fit in the sleeve of a centrifuge, and spinning them at 1,000 rpm for 30 seconds. The basket was placed in a weighing bottle to prevent further weight loss by evaporation while being weighed.

The ages of all trout were determined from the scale samples prior to processing tissues for contaminant analysis. All analyses were conducted by the Environmental Services Laboratory of the Michigan Department of Natural Resources. Other laboratory commitments limited the number of samples that could be analyzed for this study. Consequently, most of the samples submitted for analysis were composite samples of several fish of one age group of one species. It was recognized that composite samples were not desirable because of the inability to determine variability between individual fish. Analyses of individual fish were conducted only for the last three sampling periods of the study. These three samples were thus used to determine the variability of contaminants.

All trout samples analyzed for contaminants consisted of edible fillets. Sculpin samples were ground, whole fish, and they were always composite samples.

In addition to the routine samples that were taken each sampling period, additional organisms were collected as available throughout the study. These included adult salmon and their eggs during spawning periods, and salmon fry in early spring. The interest in the early fry was to determine the total body burden of chlorinated hydrocarbons received from the eggs and present at hatching.

All samples collected for this study were analyzed for the following substances:

1. Total polychlorinated biphenyls (PCB), reported as Aroclor 1254 with a lower limit of detectability of 0.2 ppm.
2. Total DDT complex, reported as DDT, with a lower limit of detectability of 0.1 ppm. Virtually all of the tissue contamination was actually DDE.
3. Dieldrin, analyzed with a lower limit of detectability of 0.01 or 0.02 ppm, depending on sample size. All samples in this study were below these levels of detectability of dieldrin.
4. Fat, reported as percent of body weight with a lower limit of detectability of 0.02%.

Results

Adult salmon

Contaminant values and percent fat in adult salmon and eggs from Pine and Bigelow creeks are given in Table 1. The sample size was intentionally kept small since comparable data were available from other sources. The Great Lakes Environmental Contaminants Survey (Anonymous 1977) measurements contained levels of PCB and DDT comparable to the values in this study. Both sets of data showed considerable variability. The 1977 Great Lakes Environmental Contaminants Survey (GLECS) reported fillets from Lake Michigan salmon, larger than 5 pounds, contained an average of 2.51 ± 1.77 ppm of PCB and 1.86 ± 1.18 ppm of DDT. This is very close to the average of 2.04 ± 0.89 ppm of PCB contained in the fillets of the salmon in this study. The DDT, however, in the GLECS survey was more than twice as high as the 0.49 ± 0.25 ppm found in the Pine and Bigelow creeks salmon.

During the 1977 spawning run it became evident that salmon eggs constituted a significant portion of the diet of resident stream trout, and consequently a potential dietary source of contaminants. The PCB levels in eggs (2.85 ± 1.91 ppm) were just slightly higher than in fillets taken from the same salmon. However, the DDT levels (0.83 ± 0.46 ppm) in the eggs were almost twice as high as the fillets (0.49 ± 0.25 ppm).

The coefficients of correlation indicated little relationship between contaminants in eggs and in fillets: PCB--r = 0.17, DDT--r = 0.16. These low correlation values may be due to the small sample size and variability, however, it obviously is not possible to use analyses from fillets in other studies to estimate dietary intake of contaminants due to eating eggs.

Stream sediments

A total of 28 sediment samples were collected in Pine and Bigelow creeks during the study. These were equally divided between samples of high organic silt content and those of almost pure sand. None of the samples ever exceeded the minimum detectable levels of DDT (0.1 ppm), PCB (0.2 ppm), or dieldrin (0.01 ppm). Hersey Creek was only sampled twice throughout the study, since contaminants were never detectable.

One sediment sample, collected in an area of organic silt, was intentionally located in the immediate proximity of a nearly decomposed, buried salmon carcass. Even this sample failed to contain detectable levels of contaminants. It thus seems obvious that the chlorinated hydrocarbons released from the decaying carcasses are flushed out of the stream system and returned to the Great Lakes.

Crayfish

Crayfish from Bigelow Creek was the only stream invertebrate sampled in sufficient quantity for contaminant analysis. Levels of DDT, PCB, dieldrin, and fat in composite samples of crayfish collected from Bigelow Creek are given in Table 2. These levels indicate that crayfish did not concentrate any of the chlorinated hydrocarbons. It was reasoned that crayfish would feed directly on salmon carcasses, and thus would reach higher levels of contamination than other invertebrates. If all invertebrates are low, direct uptake by fish through the food chain seems unlikely.

Sculpins

Levels of PCB and DDT measured in whole sculpins collected in Pine and Bigelow creeks are listed in Table 3. These levels are mostly quite low, however, the levels of PCB in the sculpins of Pine Creek reached a significant concentration. Comparable measurements in Hersey Creek never reached detectable levels.

Since the significance of chlorinated hydrocarbons in the aquatic environment was first realized, scientists have attempted to assess the importance of diverse routes of entry into aquatic organisms. Some authors have claimed the food chain to be the major contributor (Macek and Korn 1970; Harrison et al. 1970; Johnson et al. 1971), whereas others (Reinert 1967; Chadwick and Brocksen 1969; Grzenda et al. 1970; Hamelink et al. 1971) have emphasized direct uptake from the water.

The Office of Toxic Materials Control, Michigan Department of Natural Resources, has analyzed water from trout streams during salmon spawning runs and has never been able to detect any PCB or DDT (John Hesse, personal communication). Consequently, any uptake by stream fish must be through dietary sources. The most logical source of contaminants in the diet of sculpins was thought to be salmon eggs. Examination of stomachs, however, indicated that eggs were not utilized to a great extent. Numbers of eggs found in the stomachs of 131 sculpins collected during salmon spawning periods are recorded in Table 4. Salmon eggs were found in the stomachs of trout collected on these sampling dates, so it is known that eggs were available on those collection dates. It was surprising that not one egg was found in the 73 sculpins examined from Bigelow Creek. Few eggs were found in the 58 sculpins examined from Pine Creek, however, the number was sufficient to indicate that eggs were utilized as a food source. It is probably significant that the average PCB level in sculpins from Pine Creek was nearly four times as high as in those from Bigelow Creek.

None of the major food items in the diet of sculpins could be collected in sufficient quantity for analysis. Their diet consists primarily of *Gammarus*, Oligochaeta, and insect larvae, including several species of Trichoptera, Ephemeroptera, and Diptera.

Trout

Brown trout of ages I, II, and III were collected once in 1977 and twice in 1978 from Hersey Creek. Composite samples of edible fillets were analyzed for PCB, DDT, dieldrin, and fat. The composite samples varied from one to six fish each. None of the chlorinated hydrocarbons were ever present in detectable levels in any of the trout from Hersey Creek.

Most of the trout samples from Pine and Bigelow creeks were treated also as composite samples due to the limited number of analyses that could be completed by the laboratory. Only the trout collected during the last three sampling trips of 1978 were analyzed individually.

Numbers of fish in the composite samples and contaminant levels at various dates throughout the study are given in Tables 5 and 6. Many of these samples indicated a significant PCB contamination of stream trout. All fish from Pine Creek tended to be higher than corresponding fish from Bigelow Creek. This was especially true of the brown trout which tended to maintain rather low levels of PCB in Bigelow Creek. The rainbow trout from Pine Creek had the highest PCB levels, with several composite samples of five or more fish exceeding 2 ppm.

The PCB concentration of most samples was two to three times the concentration of DDT. This is approximately the same ratio measured in the adult salmon in the streams. Most samples exhibited a high level of correlation between PCB and DDT. Correlation (r) values in Bigelow Creek were: brown trout age I--r = 0.39, age II--r = 0.40, and rainbow trout age I--r = 0.86, age II--r = 0.97. Corresponding values in Pine Creek were: brown trout age I--r = 0.64, age II--r = 0.92, and rainbow trout age I--r = 0.73. Age II rainbow trout were rare due to their migratory nature. Only brown trout from Bigelow Creek, where the tissue contaminants were quite low, failed to show a significant relationship between the two chlorinated hydrocarbons.

The PCB measured in the fillets was all in the form of Aroclor 1254. Neither Aroclor 1242 nor 1260 were ever above the levels of detectability (0.2 ppm). Dieldrin also was never detectable above 0.1 ppm.

Some of the trout collected during the last three sampling trips of 1978 were analyzed as individual fish rather than composite samples. This was the first opportunity to ascertain the variability of contaminants in the resident stream fish. Composite samples were also analyzed from these collections if more fish were available than needed for individual samples. Average contaminant levels with 95% confidence limits, of individual trout collected in Pine and Bigelow creeks are listed in Table 7. These levels are mostly similar to the composite samples contained in Tables 5 and 6. The mean PCB levels of rainbow trout from Pine Creek appear to be rather low, however, corresponding composite samples from the same dates were also low (Table 5). It is possible that these rainbow trout migrated into the study area, and were not subject to sources of contamination throughout their life. The PCB level of age-II brown trout from Pine Creek, collected on July 14, 1978, is noticeably high with quite broad confidence limits. This is due to the extremely high levels (5.0 and 3.5 ppm) of two fish. These fish were also high in DDT, and had a high tissue fat percentage.

It is well known that chlorinated hydrocarbons have a high affinity for fatty tissues. It is thus reasonable to assume that trout with higher percentages of fat would accumulate higher concentrations of PCB. Coefficients of correlations of PCB levels and percent fat in fillets from the trout collected in Pine and Bigelow creeks were mostly lower than would be expected from the known relationship between lipid tissues and chlorinated hydrocarbons. Correlation values (r) in Pine Creek were: brown trout age I--r = 0.25, age II--r = 0.79, and rainbow trout age I--r = 0.75. In Bigelow Creek they were: brown trout age I--r = 0.45, age II--r = 0.34, and rainbow trout age I--r = 0.58, age II--r = 0.55. Age II rainbow trout were not available in Pine Creek. The low values are probably an indication that variability in sources of contamination plays a greater role in determining tissue concentration than does the fat content. If this is true, it is further evidence that the major source of contamination was dietary rather than direct accumulation from the water. The diet of individual trout almost certainly will vary, whereas concentrations within the water of a flowing stream are apt to be quite uniform.

An analysis of the stomach contents of trout from Pine and Bigelow creeks indicated the most likely dietary source of contaminants was salmon eggs. The major spawning period in both streams extends from early October through December, with some salmon in the streams in September, and through the winter into February. Trout fed extensively on salmon eggs throughout the spawning period. The occurrence of 20 or more eggs per trout stomach was common, and numbers ranged to a high of 72 eggs found in one age-II brown trout. Many trout were so gorged with eggs that their presence could be visually detected externally when the trout were captured. It is thus obvious that a major portion of the diet of trout, over a period of at least 90 days, was contaminated with chlorinated hydrocarbons.

Numbers and percentage contributions (by weight) of salmon eggs to the diet of trout during the 1978 spawning season is contained in Table 8. The percent contribution of salmon eggs to the diet ranged from 3.5 to 87.5%. The large confidence limits determined for many of the collections is indicative of the extreme variability in the utilization of eggs by trout. Some of the stomachs in the collection contained no eggs. The greater number of eggs in stomachs in October undoubtedly coincides with the peak of the spawning season.

If some trout utilize eggs more than others, it is reasonable that the rate of utilization would affect the uptake of chlorinated hydrocarbons. Individual contaminant levels were analyzed for 25 trout collected during the 1978 salmon spawning season. A coefficient of correlation of PCB levels in relation to the number of eggs in their stomachs was calculated. The resulting correlation (r = 0.96) indicates that some individuals tended to become habitual salmon egg eaters, and thus subject to higher dietary levels of contamination. The average contribution of eggs to the total stomach ration of all trout sampled in both study streams during October was 66% by number of items and 74% by weight.

Average numbers of major food items in trout stomachs from Pine and Bigelow creeks throughout the study are given in Table 9. Each set of data consists of the average of several individual collections. Several species each of Trichoptera, Ephemeroptera, and Diptera, in addition to salmon eggs, constituted most of the diet of the trout. The utilization of salmon eggs varied considerably with species, age, and stream. The use of Trichoptera was quite constant between streams and all sampling periods. Feeding on salmon eggs, however, seemed to completely replace the consumption of Ephemeroptera and Diptera. Both of these groups were eaten extensively between spawning periods, and almost totally ignored during spawning. It is possible that the trout switched food items by choice, but admittedly, the difference in seasons could also affect the availability of various groups of aquatic insects.

Fry

One composite sample each of coho salmon and rainbow trout fry was collected for analysis from Pine Creek in April 1978. These were newly hatched fry, and presumably any tissue contamination would have been a carry-over from the eggs. These fish were born with a significant body burden of PCB and DDT. The coho fry contained 5.8 ppm of PCB and 1.6 ppm of DDT. Their fat content was 2.9%. The PCB and DDT levels in the rainbow trout fry were 4.4 and 1.8 ppm, respectively. The fat content was 4.9%. Because of the small size of these fry, the total quantity of material in the tissues was quite small. Even if there was no metabolism with time, growth of the fish would dilute these concentrations. It is thus not possible that this initial body burden could account for the levels seen in the age-I and age-II trout.

Discussion

Resident stream trout are receiving contamination of PCB and DDT from salmon spawning runs in small Michigan trout streams. However, the original hypothesis that these chlorinated hydrocarbons are released by decaying salmon carcasses, and enter the food chain through organic stream sediments, does not appear to be true. The slow decay of a salmon carcass is accompanied by sufficient stream flushing to prevent the accumulation of released contaminants in the system. Observations of several individual carcasses, which were secured in the streams, indicate that a minimum of 60 days is required for total decomposition. Normal stream flows are apparently sufficient to dissolve and carry the released chlorinated hydrocarbons out of the streams without accumulating detectable levels in the water or sediments.

Since the contaminants released from the dead salmon are not retained in the streams, the only alternate route of entry into the stream fish is through the diet. Since crayfish did not accumulate excessive concentrations of PCB and DDT, it is probably reasonable to assume that other benthos were also relatively uncontaminated. Thus, the only possible dietary source is salmon eggs. It is obvious that many salmon eggs are lost in the spawning process. Eggs are probably lost not only during the spawning act, but also from disruption of the redds by subsequent spawners. Choice spawning areas are used repeatedly throughout the spawning season of at least 90 days.

There seemed to be a tendency for age-I trout to utilize more eggs than age-II trout, however, due to variability of samples, this difference was not statistically significant. There was also a tendency for more salmon eggs to be consumed in Pine Creek and the trout in Pine Creek accumulated higher levels of chlorinated hydrocarbons.

The high correlation between tissue levels of PCB and the number of salmon eggs in trout stomachs was unexpected. Since the one ration observed could have had essentially no effect on tissue accumulations, it is obvious that some individuals continually utilize eggs in their diet appreciably more than others. These are probably trout that reside immediately downstream from preferred spawning areas. Even though all trout were collected within approximately 200 m of stream, the availability of eggs within the sampling area was probably quite variable. It is also possible that individual trout learn to locate areas where drifting eggs are abundant.

Sculpins did not feed on eggs to the extent trout did. This lack of utilization is almost certainly due to their choice of stream habitat. They were always collected in quiet backwater pools in proximity with organic silt sediments. The salmon eggs conversely would be most abundant in the thread of the stream. The redds are located in fast riffle areas, and the eggs would be most apt to be dislodged and carried in high velocity sections.

Many scientists have assessed the effects of both PCB and DDT on various aquatic organisms. However, almost all studies have been conducted in the laboratory, under controlled conditions, and it is difficult to extrapolate potential damage to resident stream organisms. Hansen et al (1976) reported channel catfish to grow significantly slower on a diet contaminated with 20 ppm PCB; however, the fish rapidly recovered when PCB was removed from the diet. Lieb et al. (1974) noted that rainbow trout swimming performance was not affected by 15 ppm Aroclor 1254 in the diet for 224 days. Channel catfish apparently were able to eliminate a small amount of PCB while rainbow trout were not. The above two studies indicate that low levels of PCB in the diet are not permanently injurious to fish. Jarvinen et al. (1976) reported that DDT in the diet (45 ppm) of adult fathead minnows (<u>Pimephales promelas</u>) did not significantly alter hatchability of their eggs, whereas the combination of DDT in the water and diet did.

There is lack of agreement on the significance of chlorinated hydrocarbons in the human diet. The U.S. Food and Drug Administration has established an allowable level of 5 ppm for both PCB and DDT in food items. Initial steps have been taken to lower the allowable level of PCB to 2.0 ppm, however this lower limit has not been officially established. Barsotti et al. (1976) reported serious health problems in monkeys that were fed PCB (Aroclor 1248) at levels of 2.5 and 5.0 ppm in the diet. Symptoms included weight loss, loss of hair, acne, altered menstrual cycles, decreased conception rates, abortions and stillbirths. Only one of eight females fed a diet of 5 ppm for 7 months produced a normal young.

The Michigan Department of Public Health advises limited consumption of salmonid fishes from Lake Michigan because of tissue levels of both PCB and DDT. Levels of both contaminants appear to be decreasing faster than originally postulated. If the levels in Lake Michigan continue to decrease, contamination of resident stream trout will probably not constitute a health hazard. However, if the allowable tissue concentration of PCB is lowered to 2 ppm, a significant portion of the trout populations in streams with salmon spawning runs will exceed the recommended level.

Table 1.--Contaminant levels, and percent fat, in fillets and eggs from adult salmon, male or female, collected in Pine and Bigelow creeks, 1978 (95% confidence limits in parentheses).

Location, species, and sex	Collection dates	Tissues sampled: Fillets PCB (ppm)	Fillets DDT (ppm)	Fillets Fat (%)	Eggs PCB (ppm)	Eggs DDT (ppm)	Eggs Fat (%)
Bigelow Creek							
Coho salmon							
Male	12/6/78	0.75	0.16	0.88			
Female	12/6/78	1.00	0.14	0.45	1.30	0.61	1.90
Female	12/6/78	3.30	0.90	1.10	3.30	0.98	3.70
Chinook salmon							
Female	8/30/78	0.71	0.20	0.48	0.46	0.14	0.56
Female	10/10/78	1.40	0.24	0.27	9.50	1.80	7.80
Female	10/10/78	1.50	0.31	0.39	3.80	1.70	5.00
Male	10/10/78	2.60	0.59	1.10			
	10/25/78				2.30	0.65	1.40
Pine Creek							
Coho salmon							
Female	11/10/78				2.70	0.98	1.40
Female	11/10/78				1.10	0.30	1.50
Female	11/10/78				1.20	0.35	6.80
Male	12/7/78	3.00	0.90	0.96			
Male	12/7/78	4.90	1.20	1.10			
Chinook salmon							
Male	10/12/78	2.50	0.54	0.98			
Male	10/12/78	0.82	0.17	0.67			
Mean		2.04 (±0.89)	0.49 (±0.25)	0.76 (±0.22)	2.85 (±1.91)	0.83 (±0.46)	3.34 (±2.03)

Table 2.--Contaminant levels and percent fat in crayfish collected in Bigelow Creek, 1977-78.

Collection dates	PCB (ppm)	DDT (ppm)	Dieldrin (ppm)	Fat (%)
11/7/77	0.34	0.087	<0.01	1.20
11/8/77	0.26	0.075	<0.01	1.30
4/28/78	0.12	<0.01	<0.01	0.63
7/31/78	0.10	0.025	<0.01	1.10

Table 3.--Contaminant levels and percent fat in sculpins collected in Pine and Bigelow creeks, 1977-78 (95% confidence limits in parentheses).

Collection dates	Pine Creek			Bigelow Creek		
	PCB (ppm)	DDT (ppm)	Fat (%)	PCB (ppm)	DDT (ppm)	Fat (%)
10/13-14/77	0.22	0.10[a]	1.10	0.20	<0.10	0.58
11/8/77				0.35	<0.10	0.85
4/26-27/78	1.20	0.17	0.78	0.46	<0.10	0.91
4/26-27/78	1.00	0.19	1.30	0.43	<0.10	1.10
6/28/78	2.00	0.29	2.10	--	--	--
7/13-14/78	1.70	0.34	3.20	0.40	0.14	1.60
9/13/78				0.30	<0.10	0.59
10/9-10/78	0.68	0.15	2.20	<0.20[a]	<0.10	0.64
12/6-7/78	1.40	0.39	1.50			
Mean	1.17 (±0.56)	0.23 (±0.12)	1.74 (±0.76)	0.32 (±0.12)	--	0.90 (±0.34)

[a] Considered as 0.10 ppm for determining mean.

Table 4.--Total number of salmon eggs found in stomachs from sculpins collected in Pine and Bigelow creeks during salmon spawning periods, 1977-78.

Collection dates	Pine Creek		Bigelow Creek	
	Number of sculpins	Total number of eggs	Number of sculpins	Total number of eggs
10/13/77	8	0	5	0
11/8/77	7	1	23	0
1/5/78	18	0	27	0
10/9/78	6	1	7	0
12/6/78	19	7	11	0

Table 5.--Concentrations of PCB, DDT, and percent fat in composite samples of edible fillets of brown trout and rainbow trout from Pine Creek, Manistee County, Michigan, 1977-78.

Species, and age of trout	Collection dates	Number of fish	PCB (ppm)	DDT (ppm)	Fat (%)
Brown trout					
Age I	10/14/77	3	0.59	0.39	1.10
	10/14/77	4	0.80	0.63	0.97
	11/10/77	4	1.30	0.48	1.00
	11/10/77	1	0.31	0.25	0.74
	1/4/78	4	1.10	0.40	0.63
	1/4/78	2	0.74	0.36	0.73
	7/14/78	5	0.46	0.10	0.83
	10/12/78	3	0.49	0.16	0.38
Age II	11/10/77	1	1.90	0.88	1.20
	1/4/78	4	1.10	0.87	0.98
	4/26/78	3	1.50	0.20	1.20
	10/12/78	1	0.55	0.19	0.74
	10/12/78	1	0.50	0.22	0.85
Rainbow trout					
Age I	10/14/77	4	2.50	0.61	1.20
	11/10/77	10	3.80	0.62	1.50
	11/10/77	2	1.80	0.65	1.40
	1/4/78	9	1.80	0.82	1.10
	1/4/78	2	0.47	0.49	0.86
	4/26/78	2	2.00	0.43	1.10
	6/28/78	6	1.20	0.39	0.64
	7/14/78	6	1.60	0.39	0.82
	7/14/78	6	0.96	0.25	1.00
	9/14/78	3	0.29	<0.10	0.23
	10/12/78	7	0.61	0.29	1.00
	12/7/78	6	0.58	0.31	0.86
Age II	11/10/77	2	1.40	0.75	1.60
	1/4/78	5	2.90	0.79	1.10
	4/26/78	5	2.50	0.48	1.40

Table 6.--Concentrations of PCB, DDT, and percent fat in composite samples of edible fillets of brown and rainbow trout from Bigelow Creek, Newaygo County, Michigan, 1977-78.

Species, and age of trout	Collection dates	Number of fish	PCB (ppm)	DDT (ppm)	Fat (%)
Brown trout					
Age I	10/13/77	2	0.42	0.28	0.87
	11/8/77	2	1.20	0.46	1.3
	1/5/78	1	0.72	0.24	0.36
	4/27/78	2	0.64	0.14	0.56
	4/28/78	1	0.62	0.14	0.52
	7/13/78	6	0.91	1.50	0.66
	7/13/78	6	0.22	<0.10	0.54
	9/13/78	1	0.33	0.10	0.41
	9/13/78	1	0.24	<0.10	0.59
	9/13/78	4	0.29	<0.10	0.41
	10/10/78	3	0.37	0.85	0.45
Age II	10/13/78	1	0.42	0.31	0.59
	11/8/77	6	0.43	0.18	0.50
	1/5/78	6	0.50	0.26	0.44
	4/27/78	1	0.41	0.11	0.26
	4/28/78	3	0.34	<0.10	0.46
	9/13/78	1	0.34	<0.10	0.28
	9/13/78	1	0.31	<0.10	0.37
Rainbow trout					
Age I	10/13/77	3	0.20	<0.10	0.78
	10/13/77	3	0.41	0.18	0.55
	11/8/77	6	2.40	0.89	1.50
	11/8/77	5	1.00	0.45	1.30
	1/5/78	7	0.70	0.48	0.63
	1/5/78	1	2.10	0.65	1.60
	4/27/78	9	1.60	0.38	0.58
	6/27/78	3	0.54	0.14	0.69
	7/13/78	6	1.50	0.50	0.97
	9/13/78	5	<0.20	<0.10	0.19
	10/10/78	5	0.94	0.21	0.60
Age II	11/8/77	2	0.46	0.29	1.4
	1/5/78	4	4.00	2.53	1.7
	4/27/78	1	1.50	0.35	0.70
	10/10/78	1	0.67	0.18	0.61

Table 7.--Mean concentrations (with 95% confidence limits) of PCB, DDT, and percent fat in individual edible fillets of brown trout and rainbow trout from Bigelow and Pine creeks.

Species, and age of trout	Collection dates	Number of fish	PCB (ppm)	DDT (ppm)	Fat (%)
Bigelow Creek					
Brown trout					
Age I	12/6/78	6	0.49 ±0.13	0.23 ±0.03	0.96 ±0.28
Rainbow trout					
Age I	9/13/78	5	0.88 ±0.58	0.25 ±0.11	1.29 ±1.14
	12/6/78	9	0.67 ±0.16	0.25 ±0.05	0.95 ±0.16
Age II	12/6/78	3	0.56 ±0.26	0.20 ±0.13	-
Pine Creek					
Brown trout					
Age II	7/14/78	5	2.58 ±2.05	0.77 ±0.61	1.88 ±0.64
	9/14/78	5	0.51 ±0.31	0.14 ±0.06	0.25 ±0.06
	12/7/78	5	1.18 ±1.69	0.51 ±0.69	1.01 ±0.78
Rainbow trout					
Age I	9/14/78	5	0.20 ±0.11	<0.10	0.19 ±0.08
	12/7/78	6	0.45 ±0.13	0.25 ±0.08	0.80 ±0.15

Table 8.--Mean numbers of salmon eggs, and their percent (weight) of entire ration (with 95% confidence limits) in trout stomachs from Pine and Bigelow creeks during salmon spawning, 1978.

Species, and age of trout	Collection dates	Number of trout	Eggs in trout stomachs: Number of eggs: Average	Eggs in trout stomachs: Number of eggs: Range	Eggs in trout stomachs: Average percent of total ration (weight)
Pine Creek					
Brown trout					
Age I	10/12/78	3	30.3 ± 24.9	20-40	85.3 ± 7.8
Age II		2	45.0 ± 190.6	30-60	87.5 ± 95.3
Age II	12/6/78	5	17.6 ± 38.0	0-72	32.6 ± 41.6
Rainbow trout					
Age I	10/12/78	7	9.0 ± 6.6	0-23	59.1 ± 25.5
	12/6/78	6	3.8 ± 3.9	0-9	44.2 ± 38.3
Bigelow Creek					
Brown trout					
Age I	10/12/78	3	18.3 ± 44.8	0-36	31.2 ± 73.6
	12/6/78	9	2.1 ± 2.8	0-7	3.5 ± 8.1
Rainbow trout					
Age I	10/12/78	5	16.8 ± 2.8	14-20	39.6 ± 25.3
	12/6/78	8	2.8 ± 3.6	0-12	34.1 ± 30.3

Table 9.--Average number of various food items in trout stomachs during salmon spawning and non-spawning periods in Bigelow and Pine creeks (95% confidence limits in parentheses).

Period, year, and food item	Bigelow Creek				Pine Creek			
	Brown trout		Rainbow trout		Brown trout		Rainbow trout	
	I	II	I	II	I	II	I	II
Spawning periods[a]								
1977								
Salmon eggs	1.4 (±2.0)	1.2 (±1.6)	4.7 (±0.7)	0.0	7.1 (±1.6)	0.4 (±2.2)	2.3 (±0.7)	0.0
Trichoptera	9.6 (±2.5)	8.7 (±1.9)	4.3 (±1.2)	2.7 (±1.5)	3.9 (±1.9)	21.0 (±2.5)	0.9 (±1.3)	4.5 (±1.9)
Ephemeroptera	0.2 (±0.9)	0.3 (±0.7)	0.9 (±1.8)	0.7 (±2.2)	0.0	0.0	0.2 (±1.8)	0.0
Diptera	0.2 (±11.4)	0.5 (±8.9)	0.6 (±1.8)	0.0	0.1 (±8.7)	0.5 (±8.9)	0.2 (±1.8)	0.0
1978								
Salmon eggs	6.2 (±7.0)	33.0 (±3.1)	7.6 (±0.8)	5.3 (±1.1)	30.3 (±3.1)	23.9 (±1.9)	5.7 (±0.7)	-
Trichoptera	7.7 (±2.0)	0.0	8.9 (±1.3)	19.0 (±1.9)	1.0 (±3.8)	1.6 (±2.1)	1.1 (±1.3)	-
Ephemeroptera	0.8 (±0.7)	0.0	0.3 (±1.9)	0.3 (±2.8)	0.0	0.3 (±0.8)	0.1 (±1.8)	-
Diptera	0.7 (±9.0)	0.0	2.2 (±1.9)	1.8 (±2.7)	0.0	0.1 (±9.7)	0.1 (±1.8)	-
Non-spawning period[a]								
1978								
Salmon eggs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichoptera	7.6 (±1.9)	8.7 (±2.0)	3.9 (±1.2)	2.3 (±1.9)	21.5 (±2.8)	8.3 (±1.9)	11.7 (±1.2)	8.4 (±1.3)
Ephemeroptera	5.6 (±0.7)	2.6 (±0.8)	5.3 (±1.8)	11.0 (±2.8)	6.5 (±1.1)	2.6 (±0.7)	5.5 (±1.8)	2.6 (±1.9)
Diptera	34.3 (±8.7)	5.6 (±9.0)	8.1 (±1.7)	23.3 (±2.7)	2.5 (±13.0)	2.5 (±8.9)	7.6 (±1.8)	14.9 (±1.9)

[a] Sampling dates during the spawning periods were 10/13/77, 11/8/77, 1/4/78, 10/9/78, 12/6/78, and during the non-spawning periods 4/26/78, 6/27/78, 7/13/78, 9/13/78.

Literature cited

Anonymous. 1977. Great Lakes environmental contaminants survey. Mich. Dep. Agr. in cooperation with Mich. Dep. Nat. Resour., and U.S. Food and Drug Adm., 38 pp.

Barsotti, D. A., R. J. Marlar, and J. R. Allen. 1976. Reproductive dysfunction in rhesus monkeys exposed to low levels of polychlorinated biphenyls (Aroclor 1248). Sea Grant Reprint WIS-SG-76-365. Reprinted from Fd. Cosmet. Toxicol. 14: 99-104, Pergamon Press.

Chadwick, G. G., and R. W. Brocksen. 1969. Accumulation of dieldrin by fish and selected fish food organisms. J. Wildl. Manage. 33: 693-700.

Grzenda, A. R., D. F. Paris, and W. J. Taylor. 1970. The uptake, metabolism and elimination of chlorinated residues by goldfish (Carassius auratus) fed a ^{14}C-DDT contaminated diet. Trans. Am. Fish. Soc. 99: 385-395.

Hamelink, J. L., R. C. Waybrant, and R. C. Ball. 1971. A proposal: exchange equilibria control the degree chlorinated hydrocarbons are biologically magnified in lentic environments. Trans. Am. Fish. Soc. 100: 207-214.

Hansen, L. G., W. B. Wiekhorst, and J. Simon. 1976. Effects of dietary Aroclor 1242 on channel catfish (Ictalurus punctatus) and the selective accumulation of PCB components. J. Fish. Res. Board Can. 33: 1343-1352.

Harrison, H. L., O. L. Loacks, J. W. Mitchill, D. F. Parkhurst, C. R. Tracy, D. G. Watts, and V. J. Yannacone, Jr. 1970. Systems studies of DDT transport. Science 170: 503-508.

Jarvinen, A. W., M. J. Hoffman, and T. W. Thorslund. 1976. Toxicity of DDT food and water exposure to fathead minnows. U.S. Env. Protection Agency, Ecol. Res. Ser., DPA-600/3-76-114.

Johnson, T. B., R. C. Saunders, H. O. Sanders, and R. S. Campbell. 1971. Biological magnification and degradation of DDT and aldrin by fresh-water invertebrates. Fish. Res. Board Can. 28: 705-709.

Lieb, A. J., D. D. Bills, and R. O. Sinnhuber. 1974. Accumulation of dietary polychlorinated biphenyls (Aroclor 1254) by rainbow trout (Salmo gairdneri). J. Agr. Food Chem. 22: 637-642.

Macek, K. J., and S. Korn. 1970. Significance of the food chain in DDT accumulation by fish. J. Fish. Res. Board Can. 27: 1496-1498.

Odum, W. E., G. M. Woodwell, and C. F. Wurster. 1969. DDT residues absorbed from organic detritus by fiddler crabs. Science 164: 576-577.

Pennak, R. W. 1958. Freshwater invertebrates of the United States. The Ronald Press Co., New York.

Reinert, R. E. 1967. The accumulation of dieldrin in an alga (Schenedesmus obliquus), Daphnia (Daphnia magna), guppy (Lebistes reticulatus) food chain. Ph.D. Thesis, Univ. Mich., Ann Arbor, 76 pp.

Risebrough, R. W., P. Rieche, D. B. Peakall, S. G. Herman, and M. N. Kirven. 1968. Polychlorinated biphenyls in the global ecosystem. Nature 220: 1098-1102.

Snarski, V. M., and F. A. Puglisi. 1976. Effects of Aroclor 1254 on brook trout, Salvelinus fontinalis. U.S. Env. Protection Agency, Ecol. Res. Ser. EPA-600/3-76-112.

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