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REPRODUCTIVE FAILURE AND MORTALITY IN MINK FED ON GREAT LAKES FISH*

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Summary. Experiments were conducted from 1968 to 1971 inclusive to investigate reproductive complications and mortality in mink attributed to the use of Lake Michigan coho salmon in the ration (Aulerich, Ringer, Seagran & Youatt, 1971). The results indicated that coho salmon as such was not responsible for the loss in fertility. Mink rations that contained other species of Great Lakes fish caused similar reproductive complications, but to a lesser degree. The toxic factor(s) appeared to be concentrated in coho salmon canning by-products, which when fed to adult mink as 30% of the diet were lethal within 3 months. The coho salmon fed to mink during the later feeding trials appeared to be more toxic than that fed in the earlier experiments.

Rancidity or mercury contamination of the fish was ruled out as being responsible for the problem. A direct relationship between the extent of reproductive failure in the mink and the chlorinated hydrocarbon pesticide content of the fish was demonstrated, but no clinical signs of chlorinated hydrocarbon pesticide poisoning were detected in the mink. The clinical signs and lesions noted in mink that died while receiving diets that contained Lake Michigan coho salmon were very similar to those observed in mink fed on rations that contained 30 parts/10^6 supplemental PCBs. These included anorexia, bloody stools, fatty liver and kidney degeneration, and haemorrhagic gastric ulcers. Analyses of the tissues from mink that died while fed on diets containing Lake Michigan coho salmon or 30 parts/10^6 supplemental PCBs showed similar PCB residues, which averaged about 11 parts/10^6 in the brain. Feeding mink on diets that contained 10 parts/10^6 PCB, alone or in combination with chlorinated hydrocarbon pesticides, depressed growth. A PCB-toxicity experiment revealed that mink are very sensitive to these compounds and that the toxicity varies inversely with the chlorine content of the PCBs.

INTRODUCTION

For many years the Great Lakes fisheries supplied the United States and Canadian mink ranching industries with an abundant supply of fish for feeding. The utilization of Great Lakes fish, however, has diminished since the mid-1960s,

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due to reports of reproductive complications when mink were fed in this way (Hartsough, 1965). An acute problem was evident when coho salmon, taken from tributaries of Lake Michigan during the spawning run in the autumn of 1967, were purchased by commercial mink ranchers and fed to mink before and during the reproductive period in 1968. Rations that contained up to 15% of ground, whole, raw coho salmon were fed to mink. The adult animals were not adversely affected. Breeding and whelping were reported as normal, but kit mortality reaching 80% was reported and appeared to depend upon the percentage of coho salmon fed, as well as the duration of feeding. The cause of the problem was not determined, although rancidity, pesticides and other contaminants were suspected.

Because of the human health implications and the economic importance of the Great Lakes fisheries to the mink and pet food industries, this study was initiated to investigate the problem.

METHODS AND MATERIALS

The study comprised five feeding experiments. Experiment 1 was conducted from 20th July 1968 to 30th June 1969, to determine the effects of long-term feeding of coho salmon to mink. Experiment 2 was conducted from 10th December 1968 to 30th June 1969, Exp. 3 from 1st January 1970 to 30th June 1970 and Exp. 4 from 1st January 1971 to 30th June 1971. A fifth feeding trial was started on 25th August 1971 and ended on 30th June 1972. A standard ranch diet (Table 1) was used throughout the study. In each trial the mink were fed on

Table 1. Composition of basal diet

Ingredients	*Percentage*
Supplemented cereal*	15·0
Tripe	20·0
Beef liver	5·0
Horsemeat	15·0
'Spent' chicken†	15·0
Fish	30·0

* Kel-blend No. 1009, W. K. Kellogg Co., Battle Creek, Michigan.
† For description see Aulerich & Schaible (1966).

diets that differed only in the fish component of the ration (Table 2) or in the supplementation of the standard diet that contained ocean fish with polychlorinated biphenyls or chlorinated hydrocarbon pesticides.

In Exp. 1, five male and ten female mink (natural darks and pastels) were fed on a diet that contained 30% coho salmon taken in 1967 from Lake Michigan tributaries. These salmon were obtained from a mink feed supplier and were from the same origin as those earlier suspected of having caused reproductive complications in mink. Seven male and fourteen female mink served as controls and were fed ocean perch. In Exps 2, 3 and 4, three male and twelve female mink (natural darks and pastels) were placed on each dietary treatment. The 30 parts/10^6 polychlorinated biphenyl (PCB) supplementation of the basal diet in Exp. 4 consisted of 10 parts/10^6 each of 'Aroclors' 1242, 1248 and 1254 (Monsanto Co., St. Louis, Mo.). Experiment 5 was designed to investigate possible interactions between a PCB ('Aroclor 1254') and chlorinated hydrocarbon pesticides when these compounds were fed to mink. Six female and one male natural dark mink kits were placed on each dietary treatment.

No mink employed in any experiment had previously received Great Lakes fish or supplemental PCBs in its diet. Standard ranch procedures were followed

Table 2. Fish portion of rations fed to mink in Experiments 1, 2, 3, 4 and 5

Experiment	*Fish component of diet*
1	1968 Ocean perch, *Sebastes marinus*(a)
	1967 Lake Michigan coho salmon, *Oncorhynchus kisutch*(b)
2	1968 Ocean whiting, *Merluccius bilinearis*(c)
	1968 West Coast (Oregon) coho salmon, *O. kisutch*(d)
	1967 Lake Michigan coho salmon, *O. kisutch*(b)
	1968 Lake Michigan coho salmon, *O. kisutch*(e)
	1968 Lake Michigan coho salmon, *O. kisutch*, canning by-products(f)
3	1969 Ocean whiting, *M. bilinearis*(g)
	1969 Lake Michigan coho salmon, *O. kisutch*(h)
	1969 Lake Michigan bloater chub, *Coregonus hoyi*(i)
	1969 Lake Erie coho salmon, *O. kisutch*(j)
	1969 Lake Michigan yellow perch, *Perca flavescens*(i)
	1969 Lake Erie yellow perch, *P. flavescens*(i)
4	1970 Ocean fish mix—cod, *Gadus morhau*, haddock, *Melanogrammus aeglefinus*, and flounder, *Liopsetta obscura*(c)
	1970 Lake Michigan coho salmon, *O. kisutch*(h)
5	1970 Ocean fish mix—cod, *G. morhau*, haddock, *M. aeglefinus*, and flounder(c)

Sources: (a) Boston Feed Supply, Boston, Massachusetts; (b) Lewis Fur Farms, Rodney, Michigan; (c) National Food Company, New Holstein, Wisconsin; (d) Trask River Fish Hatchery, Oregon Fish Commission, Portland, Oregon; (e) Little Manistee River Weir, Michigan Department of Natural Resources, Lansing, Michigan; (f) Blackport Packing Company, Grand Rapids, Michigan; (g) Point Judith Fish Cooperative, Point Judith, Rhode Island; (h) Platt River Weir, Michigan Department of Natural Resources, Lansing, Michigan; (i) National Marine Fisheries Service, Ann Arbor, Michigan; (j) Pennsylvania Fish Commission, Harrisburg, Pennsylvania.

in feeding, breeding and caring for the animals. The mink were vaccinated as kits against canine distemper, botulism and virus enteritis. During the maintenance and breeding seasons, they were fed to condition them for optimum reproduction. Whenever possible, the females were mated with males within their respective dietary groups. Each female was mated at least once. All matings were verified by the presence of apparently normal motile spermatozoa in the vaginal smear after copulation.

The mated females were checked daily for young during the whelping period. Kits were counted and weighed on the day of birth and at 4 weeks of age.

Adult mink were given single i.p. injections of either Aroclors 1221, 1242 or 1254 to ascertain the acute toxicity (LD_{50}) of these PCBs. Injections of corn oil were used for control purposes. Gavage of PCBs proved unsatisfactory as frequent vomiting occurred.

RESULTS

Reproduction

Reproductive failure (Tables 3 and 4) occurred in females fed on any diet that contained Lake Michigan coho salmon and, of sixty-five females fed on such diets, fifty-nine failed to whelp (Exps 1 to 4). The six females that whelped had only ten kits and of these eight were stillborn and the two that were born alive died within 24 hr. Teratism was not observed in the kits. The reproductive performance of the females fed on the West Coast coho salmon was not impaired and in many respects was superior to that of mink fed on the control rations.

Table 3. Reproductive performance of mink fed on various fish

Exp. no.	*Fish portion of diet*		*No. of females*		*No. of kits*		
			Mated	*Whelped*	*Birth Alive*	*Birth Dead*	*4 weeks* alive*
1 (20th July to 30th June)	1968	Ocean perch (control)	14*	13	48	9	46
	1967	L. Mich. coho salmon	8	0	0	0	0
2 (10th Dec to 30th June)	1968	Ocean whiting (control)	11*	10	38	2	31
	1968	West Coast coho salmon	12	11	58	7	47
	1967	L. Mich. coho salmon	12	5	2	7	0
	1968	L. Mich. coho salmon	12	0	0	0	0
	1968	L. Mich. coho salmon canning by-products	11*	0	0	0	0
3 (1st Jan to 30th June)	1969	Ocean whiting (control)	12	10	45	10	29
	1969	L. Mich. coho salmon	10†	1	0	1	0
	1969	L. Mich. bloater chub	12	7	10	12	5
	1969	L. Erie coho salmon	12	11‡	32	17	7
	1969	L. Mich yellow perch	12	10	31	7	15
	1969	L. Erie yellow perch	12	10	39	12	28

* One died before mating.
† Two died before mating.
‡ One mated female died before whelping.

Poor reproduction occurred in mink fed on rations that contained Lake Michigan bloater chub. Only 58% of the females that received bloater chub in their diet whelped, and 55% of the kits were stillborn. The average litter size was not greatly reduced in animals fed on the rations that contained Lake Erie coho salmon and Lake Erie or Lake Michigan yellow perch (Table 3).

No evidence of whelping was observed in those females that survived to term on the diet that contained supplemental PCBs (Table 4).

The mean length of gestation per group ranged from 47 to 56 days and was not influenced by dietary treatment.

Kit mortality and body weights

No kit survived longer than 24 hr after birth on diets that contained Lake Michigan coho salmon. Excessive kit mortality (50% or more) was noted

Table. 4. Reproductive performance of control mink and mink fed on rations that contained coho salmon or supplemental PCBs. (Experiment 4, 1st January to 30th June)

	Dietary treatment		
	Control 30% *ocean fish mix*	30% *coho salmon*	30% *ocean fish mix plus* 30 *parts*/10^6 *PCBs**
No. females mated	12	12	11†
No. females whelped	11	0	0
No. kits born			
Alive	35	—	—
Dead	19	—	—
No. live kits at 4 weeks	29	—	—

* The PCB supplementation consisted of 10 parts/10^6 each of Aroclors 1242, 1248 and 1254.
† One female died before the mating season.

on diets that contained Lake Erie coho salmon, Lake Michigan bloater chub and Lake Michigan yellow perch.

The average body weight at birth of the kits from females fed on the diet that contained Lake Michigan bloater chub was significantly less ($P < 0{\cdot}05$) than that of the kits from females fed on the control diet that contained ocean whiting (Table 5). The average body weights of 4-week-old kits nursed by females fed on diets that contained West Coast coho salmon, Lake Erie coho salmon, Lake Michigan bloater chub and Lake Michigan yellow perch were significantly less ($P < 0{\cdot}01$) than those nursed by females fed the ocean whiting control rations (Table 5).

Adult mortality

All mink that received Lake Michigan coho salmon canning by-products or 30 parts/10^6 supplemental PCBs (Tables 3 and 4) in their diet died between the beginning of the breeding season and the end of the whelping period. Four females and two males, fed on the diet that contained Lake Michigan coho

Table 5. Average body weight (± S.E.) of live kits at birth and 4 weeks

Exp.		*Fish portion of diet*	*At birth* *No.*	*At birth* *Body wt (g)*	*At 4 weeks* *No.*	*At 4 weeks* *Body wt (g)*
2	1968	Ocean whiting (control)	38	9·2±0·38	31	162±5·4
	1968	West Coast coho salmon	56	9·4±0·17	47	138±4·1**
	1967	L. Mich. coho salmon	2	5·3±0·80	0	—
3	1969	Ocean whiting (control)	45	8·2±0·23	29	125±3·8
	1969	L. Mich. bloater chub	10	7·0±0·59*	5	91±13·2**
	1969	L. Erie coho salmon	32	7·6±0·20	7	86±9·3**
	1969	L. Mich. yellow perch	36	8·3±0·35	15	104±7·2**
	1969	L. Erie yellow perch	39	8·2±0·22	28	122±3·9

* Significant difference from controls ($P < 0{\cdot}05$) by *t*-test.
** Significant difference from controls ($P < 0{\cdot}01$) by *t*-test.

Table 6. Peroxide values and mercury content of fish fed to mink in Experiment 3 in 1969

Fish	*Peroxide value** (*mequiv. peroxide/kg fat*)	*Total mercury†* (*parts/10^6*)
Ocean whiting (control)	165·0	0·08
Lake Michigan coho salmon	36·7	0·30
Lake Michigan bloater chub	6·7	0·10
Lake Erie coho salmon	110·0	0·36
Lake Michigan yellow perch	50·3	0·18
Lake Erie yellow perch	130·8	0·25

* Analyses by National Marine Fisheries Service, Ann Arbor, Michigan.
† Analyses by Wisconsin Alumni Research Foundation, Madison, Wisconsin.

salmon in Exp. 1, and six of the fifteen mink fed on Lake Michigan coho salmon in Exp. 4, died during the latter stages of the experiments. The clinical signs and lesions in mink that died on diets which contained coho salmon canning by-products, whole coho salmon from Lake Michigan, or supplemental PCBs were similar, and consisted of anorexia, bloody stools, fatty infiltration and degeneration of the liver and kidneys, and haemorrhagic gastric ulcers. Antibiotic

Table 7. Pesticide and fat content of the fish and complete diets fed to mink in Experiment 3* in 1969

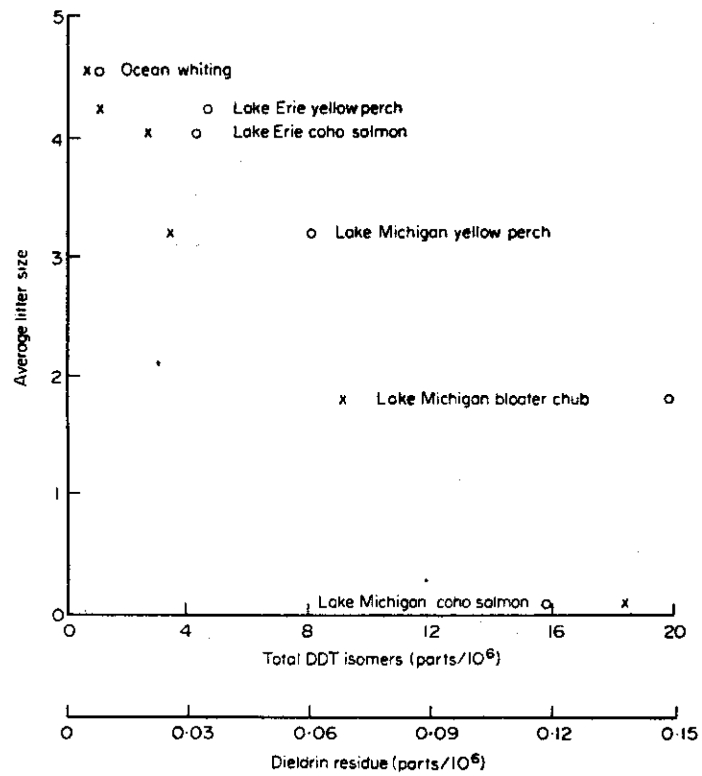
Fish	*Diet*	*pp' DDE*	*op- DDT*	*pp' DDD*	*pp' DDT*	*Total DDT*	*Dieldrin*	*% fat*
Lake Michigan coho salmon		10·12	2·68	1·77	3·66	18·23	0·118	5·8
	30% Lake Michigan coho salmon	1·46	0·28	0·25	0·50	2·49	0·01	5·5
Lake Erie coho salmon		0·83	0·43	0·73	0·77	2·76	0·031	3·2
	30% Lake Erie coho salmon	0·12	0·08	0·10	0·10	0·40	0·022	4·9
Lake Michigan bloater chub		3·87	1·26	0·89	2·79	8·81	0·149	19·8
	30% Lake Michigan bloater chub	0·67	0·31	0·23	0·66	1·87	0·025	8·7
Lake Michigan yellow perch		0·92	0·61	0·70	1·11	3·34	0·061	7·5
	30% Lake Michigan yellow perch	0·16	0·08	0·10	0·14	0·48	0·014	5·3
Lake Erie yellow perch		0·22	0·17	0·29	0·36	1·04	0·037	5·5
	30% Lake Erie yellow perch	0·05	0·05	0·07	0·05	0·22	0·01	5·6
Ocean whiting		0·15	0·13	0·18	0·18	0·64	0·010	4·9
	30% Ocean whiting	0·02	0·04	0·03	0·03	0·12	0·01	5·3

* Analyses by National Marine Fisheries Service, Ann Arbor, Michigan.

treatment and injections of iron, vitamins A, D and E, and the B-complex vitamins did not arrest mortality among the mink that were fed on coho salmon. Histopathologic examination and bacterial cultures of tissues from these mink failed to reveal the cause of the pathological symptoms.

Fish quality

Peroxide values of the fish used in Exp. 3 are shown in Table 6. The peroxide values ranged from 6·7 to 165·0 mequiv. peroxide/kg fat. There was no correlation between the state of oxidative rancidity of the fish (as indicated by the peroxide values) and the dietary differences observed. Ocean whiting used in the



TEXT-FIG. 1. Relationship between litter size and pesticide residues (×, DDT; o, Dieldrin) in fish fed to mink in Experiment 3.

control ration showed the greatest oxidative rancidity of any fish fed in Exp. 3, yet it supported the best reproduction and kit growth.

The mercury content of the various fish used in Exp. 3 (Table 6) ranged from 0·08 parts/10^6 (ocean whiting, control) to 0·36 parts/10^6 in the Lake Erie coho salmon. No association was evident between the mercury content of the fish and reproductive performance or kit mortality observed in the mink.

Pesticide residues in the fish and the complete diets fed to mink in Exp. 3 are shown in Table 7. Total DDT residue in the fish varied from 18·23 parts/10^6 in Lake Michigan coho salmon to 0·64 parts/10^6 in ocean whiting. Dieldrin

Table 8. Average PCB residues in tissues from control mink and mink that died while receiving diets that contained coho salmon or supplemental PCBs*; Experiment 4

Dietary treatment	No. mink	PCB tissue residue (parts/10^6) ± S.E.						
		Brain	Liver	Kidney	Spleen	Lung	Muscle	Heart
30% Ocean fish mix control	4	<0·01	<0·01	<0·01	<0·01	<0·01	N.D.‡	N.D.
30% Lake Michigan coho salmon	3	11·07 ±0·78	5·21 ±1·66	6·37 ±0·25	6·19 ±0·09	5·15 ±0·22	4·73 ±1·80	2·84 ±1·21
30% Ocean fish mix plus 30 parts/10^6 PCBs†	12	11·00 ±1·43	4·18 ±0·58	4·47 ±0·42	4·79 ±0·39	4·78 ±0·53	4·88 ±0·54	3·26 ±0·49

* Analyses by M.S.U. Pesticide Research Center.
† PCBs consisted of 10 parts/10^6 each of Aroclors 1242, 1248 and 1254.
‡ None detected.

content of the fish ranged from 0·149 parts/10^6 in Lake Michigan bloater chub to 0·01 parts/10^6 in ocean whiting. A data plot of litter size/female mated versus total DDT isomers or dieldrin residue in the fish fed to mink in Exp. 3 indicates a relationship (Text-fig. 1). No clinical signs of chlorinated hydrocarbon pesticide toxicity, such as tremors, convulsions or loss of co-ordination, however, were observed in the mink fed on the Great Lakes fish diets.

In addition to the pesticide residues, analyses of the Lake Michigan coho salmon used in these experiments showed PCB residues ranging from 10 to 15 parts/10^6. Thus, Exps 4 and 5 were conducted to investigate the possible involvement of the PCBs.

PCB implications

PCB analyses were made in Exp. 4 on selected tissues from the animals that died while receiving diets which contained Lake Michigan coho salmon or 30 parts/10^6 PCB. The results, along with those obtained from control mink, are summarized in Table 8. Although PCBs are known to accumulate in adipose

Table 9. Mean organ weights* of control mink and mink that died on rations that contained coho salmon or supplemental PCBs; Experiment 4

	Dietary treatment		
	Control 30% ocean fish mix	30% coho salmon	30% ocean fish mix plus 30 parts/10^6 PCBs†
No. mink (♀)	7	3	11
Organ			
Heart: mean wt (g) ± S.E.	75·8 ± 4·75	76·3 ± 18·51	72·9 ± 4·23
Liver: mean wt (g) ± S.E.	399·5 ± 48·68	383·8 ± 19·04	397·2 ± 24·1
Kidney: mean wt (g) ± S.E.	65·3 ± 3·09	67·6 ± 5·76	70·2 ± 3·94
Spleen: mean wt (g) ± S.E.	35·5 ± 5·92	32·3 ± 11·78	29·3 ± 6·45

* Expressed as per cent of brain weight.
† The PCB supplementation consisted of 10 parts/10^6 each of Aroclors 1242, 1248 and 1254.

Table 10. Effect of a PCB (Aroclor 1254) alone and in combination with pesticides on body-weight gains of female mink; Experiment 5

Dietary treatment	No. mink	Initial body wt (g) (25th Aug.)	Body-weight gain from initial weight (g) ± S.E.			
			1 month (24th Sept.)	2 months (25th Oct.)	3 months (25th Nov.)	4 months (22nd Dec.)
Exp. 1 Basal diet 30% ocean fish mix (control)	6	1020	43 ± 17·4	203 ± 25·4	187 ± 46·2	210 ± 35·1
Exp. 2 Basal diet plus 5 parts/10^6 PCB	6	940	62 ± 22·4	153 ± 44·2	138 ± 42·7	128 ± 43·7
Exp. 3 Basal diet plus 10 parts/10^6 PCB	6	923	43 ± 20·4	148 ± 32·0	132 ± 26·3	92 ± 35·1*
Exp. 4 Basal diet plus 10 parts/10^6 PCB and 10 parts/10^6 DDT	6	1052	43 ± 14·5	57 ± 14·6**	28 ± 21·5**	−15 ± 35·4**
Exp. 5 Basal diet plus 10 parts/10^6 PCB and 0·5 parts/10^6 dieldrin	6	940	108 ± 25·1	133 ± 26·7	115 ± 18·9	57 ± 24·4**

* Significantly different ($P < 0·05$) from controls.
** Significantly different ($P < 0·01$) from controls.

tissue, no samples of body fat were available for analysis, since the animals fed on coho salmon and PCBs were emaciated at the time of death.

As shown in Table 8, comparable quantities of PCBs accumulated in the tissues of mink that died while receiving the diet containing Lake Michigan coho salmon or the basal ration (30% ocean fish mix) supplemented with 30 parts/10^6 PCBs. The PCB residues in the brain of these mink averaged about 11 parts/10^6 and were approximately twice those observed in other tissues.

The mean organ weights (expressed as a percentage of brain weight) of female mink that died in Exp. 4 are shown in Table 9, along with equivalent data for seven control animals. Analysis of variance of organ weights showed no significant differences ($P < 0{\cdot}05$) between the various dietary treatments.

Average weight gains of female mink fed on the control ration or the diets supplemented with PCB (Aroclor 1254) and chlorinated hydrocarbon pesticides in Exp. 5 are shown in Table 10. Four months of feeding 5 and 10 parts/10^6 PCB or 10 parts/10^6 PCB plus 0·5 parts/10^6 dieldrin reduced weight gain in the mink. However, only 2 months of feeding 10 parts/10^6 PCBs plus 10 parts/10^6 DDT produced a highly significant reduction in growth and, after 4 months, loss of weight. No data about reproduction in the mink in Exp. 5 are available at present.

The relative toxicities (LD_{50})/48 hr of the three PCBs, Aroclors 1221, 1242 and 1254 when administered to mink as a single i.p. injection are 250 to 500 parts/10^6, 500 to 1000 parts/10^6 and about 1,000 parts/10^6, respectively. Among the Aroclors tested, the PCB toxicity to the mink increased inversely with the chlorine content (last two digits of the Aroclor number) of the compounds.

DISCUSSION

The results indicate that reproductive failure occurs from feeding Lake Michigan coho salmon as 30% of the diet. However, the causative agent does not appear to be the coho salmon as such, nor to be confined to coho salmon. Other species of freshwater fish from the Great Lakes fed to mink at 30% of the diet also produced adverse reproductive effects, but differing in degree. More acute reproductive complications occurred in mink that were fed on diets which contained fish from Lake Michigan than in those on rations containing similar species of fish from Lake Erie or the West Coast. The factor or factors responsible for the effect on reproduction were apparently concentrated in the canning by-product (heads, tails, fins and viscera) of the coho salmon. When the by-product was fed to adult animals as 30% of the diet for about 3 months, it was lethal. Also, the loss of adult mink on the various feeding trials involving whole, raw, Lake Michigan coho salmon, shows that prolonged feeding of the whole fish, as well as the by-product, can be toxic to mink of all ages. As indicated by the reproductive performance and mortality observed in Exps 2, 3 and 4, in which Lake Michigan coho salmon obtained from 1967 through to 1970 was fed to mink at the same percentage of the diet for similar time periods, the toxic effects of the fish have become more acute with each successive feeding trial.

The suspicion that rancidity or mercury contamination of the dietary fish was implicated in the inferior reproduction was unfounded; the data suggested a relationship between the reproductive performance of the mink and the amount of pesticide residue (total DDT isomers or dieldrin) in the fish.

If it is assumed that an adult female mink consumes about 150 g of feed/day (Schaible, 1970), the total intake of DDT and its metabolites by a whelping female fed on the Lake Michigan coho salmon ration over a 4-month period would be about 45 mg. The females that received the ration containing Lake Michigan bloater chub (highest in dieldrin content) would have consumed about 0·45 mg of dieldrin per female during that period. To judge from the results of other studies with mink (Duby, 1970; Aulerich & Ringer, 1970), these levels of DDT or dieldrin would apparently not cause reproductive failure to the extent noted in this study. Levels as high as 150 parts/10^6 total DDT (commercial grade) fed to mink from weaning through whelping did not impair reproduction (Aulerich & Ringer, 1970).

The relative PCB toxicity to mink indicates that these compounds are considerably more toxic to mink than to rats (Tucker & Crabtree, 1970; Kimbrough, 1971), mice (Nishizumi, 1970) or birds (Tucker & Crabtree, 1970; Heath, Spann, Kreitzer & Vance, 1970). Although some investigators (Risebrough & Brodine, 1970; Prestt, Jefferies & Moore, 1970) have reported a positive relationship between the percentage of chlorine in PCBs and their relative toxicity, the toxicity of the Aroclors tested with mink in this study varied inversely with the percentage of chlorine in the compounds. Lichtenstein, Schulz, Fuhremann & Liang (1969) noted a similar relationship in the toxicity of PCB to flies, and Kimbrough (1971) reported that Aroclor 1254 was more toxic to rats than Aroclor 1260.

The more commonly reported pathological effects of exposure to PCB in mammals have been associated with liver damage (Bennett, Drinker & Warren, 1938; Miller, 1944; Peakall & Lincer, 1970). To the authors' knowledge, no previous accounts of gastric ulcers, as noted in this study, have been reported. Although the reproductive complications observed in the mink fed on Great Lakes fish may be attributable to hormonal imbalances resulting from PCB induction of liver microsomal enzyme activity, as demonstrated in the rat by Street, Urry, Wagstaff & Blau (1969), the significance of the haemorrhagic gastric ulcers has not been determined.

The PCB residual content of Lake Michigan coho salmon and the sensitivity of mink to PCBs, as well as the similarity in the clinical signs and lesions observed in the mink that died while receiving diets that contained coho salmon and PCBs, and the accumulation of comparable quantities of PCB residues in the tissues of these animals, strongly suggest that polychlorinated biphenyls may be, in part, responsible for the problem. The mink growth data (Exp. 5) presented in Table 13, in which PCB (Aroclor 1254) was fed to mink alone and in combination with DDT or dieldrin support this supposition. Although no significant differences ($P < 0{\cdot}05$) were found between the weight gains of the mink that received 10 parts/10^6 PCB alone (Table 10; Exp. 3) and those that were fed 10 parts/10^6 PCB plus DDT (Exp. 4) or dieldrin (Exp. 5), a trend toward greater growth depression occurred on the diets that contained both PCB and chlorinated hydrocarbon pesticides. A synergistic effect of PCBs on DDT has been demonstrated in insects by Tsao, Sullivan & Hornstein (1953). Lichtenstein *et al.* (1969) also reported an interaction between Aroclors and DDT or dieldrin in which the toxicities of the pesticides were significantly increased. Additional studies are being conducted to investigate this aspect and to substantiate further the supposition that PCB contamination of Great Lakes fish is the primary factor responsible for this problem.

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