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Effects of feeding coho salmon and other Great Lakes fish on mink reproduction[1]

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Feeding experiments were conducted to investigate reproductive problems attributed to the feeding of Great Lakes coho salmon to mink. Several other species of fish were fed for comparison. Whole, raw, sexually mature coho salmon taken from tributaries of Lake Michigan were ground, mixed into a diet at a 30% level, and fed to mink before breeding and during gestation. This diet caused reproductive failure and (or) very early kit mortality. Feeding canning by-products of coho salmon from the same source and at the same level to adult mink for 3 months resulted in mortality. Reduced reproductive performance and (or) excessive kit mortality were observed in mink which were fed diets that contained Lake Michigan bloater chub, Lake Michigan yellow perch, and mature coho from the Lake Erie system. Mink rations which contained West Coast coho salmon and Lake Erie yellow perch did not impair reproduction nor result in excessive mortality.

No correlation was found between the degree of oxidative rancidity or mercury contamination of the fish and the reproductive performance of the mink. The levels of pesticide residues in the fish (and the complete diets) and the degree of reproductive decline and (or) kit mortality observed in the mink appeared related.

The study demonstrated that coho salmon per se does not cause the reproduction and mortality problems. Further, the disorder is also associated with other species of Great Lakes fish and appears to be dependent upon the species of fish and its environment.

Introduction

During 1967, sexually mature coho salmon taken from tributaries of Lake Michigan during the spawning run were purchased by commercial mink ranchers for mink feed. Rations which contained up to 15% of ground, whole, raw coho salmon were fed to mink before and (or) during the reproductive period. The adult animals were not adversely affected by the coho salmon. Breeding and whelping were reported as normal; however, kit mortality as high as 80% was reported and appeared to be dependent upon the percentage of coho salmon fed, as well as the duration of feeding.

The cause of the problem has not been ascertained; pesticides and various other contaminants have been implicated, but not established to be the cause of the difficulty. Because the reproductive complications encountered in feeding coho salmon to mink may influence the future use of Great Lakes coho salmon (and coho salmon by-products) as well as other species of fish by the pet food and mink industries, a study was initiated to investigate the problem.

Methods

The study consisted of three mink feeding trials. Experiment I was conducted from July 20, 1968, to June 30, 1969, to determine the effects of long-term feeding of coho salmon on mink. Experiment II was conducted from December 10, 1968, to June 30, 1969, and experiment III from January 1, 1970, to June 30, 1970. In each feeding trial the mink were fed a basal diet (Table 1) which differed only in the fish component of the ration as indicated in Table 2.

In experiment I, 5 male and 10 female mink (natural darks and pastels) were fed a diet which contained 30% coho salmon taken in 1967 from Lake Michigan tributaries. The coho salmon were obtained from a mink feed supplier and were suspected of earlier having caused reproductive complications in mink. Seven male and 14

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female mink served as controls and were fed an identical ration except that the fish component of the diet consisted of ocean perch rather than coho salmon. In experiments II and III, 3 male and 12 female mink (natural darks and pastels) were placed on each of the dietary treatments shown in Table 2. None of the animals used in the feeding trials had previously received Great Lakes fish in their diet.

Standard ranch procedures were followed in feeding, breeding, and caring for the animals. The mink were vaccinated as kits for canine distemper, botulism, and virus enteritis and revaccinated before the breeding season. During the maintenance and breeding season, the mink were fed to condition them for optimum reproduction.

Breeding attempts were initiated the first week in March. Each female was given an opportunity to mate every fourth day until a successful mating was attained. An attempt was made to remate the females (usually to the same male) either the day after the initial successful mating or 8 days later. Whenever possible, the females were mated to males within their respective dietary groups. All matings were verified by taking a vaginal smear from the females after copulation and observing it under the microscope for the presence of normal appearing, motile sperm.

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

TABLE 1

Composition of basal diet

Ingredients	%
Supplemented cereal[a]	15.0
Tripe	20.0
Liver (inedible beef)	5.0
Horsemeat	15.0
"Spent" chicken[b]	15.0
Fish	30.0

[a]Kel-blend No. 1009, W. K. Kellogg Co., Battle Creek, Michigan.
[b]For description see Aulerich, R. J. and P. J. Schnible. 1966. Simple method of processing "spent" chickens for mink feeding and their use during late growth and furring. Mich. Agr. Exp. Sta. Quart. Bull. 49(3): 24–27.

TABLE 2

Experimental design of mink feeding experiments I, II, and III

Expt.	Fish component of diet
I	1968 ocean perch (*Sebastes marinus*)[a] 1967 Lake Mich. coho salmon (*Oncorhynchus kisutch*)[b]
II	1968 ocean whiting (*Merluccius bilinearis*)[c] 1968 West Coast (Oregon) coho salmon (*O. kisutch*)[d] 1967 Lake Mich. coho salmon (*O. kisutch*)[b] 1968 Lake Mich. coho salmon (*O. kisutch*)[e] 1968 Lake Mich. coho salmon (*O. kisutch*) canning by-products[f]
III	1969 ocean whiting (*M. bilinearis*)[g] 1969 Lake Mich. coho salmon (*O. kisutch*)[h] 1969 Lake Mich. bloater chub (*Coregonus hoyi*)[i] 1969 Lake Erie coho salmon (*O. kisutch*)[j] 1969 Lake Mich. yellow perch (*Perca flavescens*)[k] 1969 Lake Erie yellow perch (*P. flavescens*)[l]

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

Results

Reproduction

No complications were encountered in mating the mink. Each female was mated at least once. The average number of matings per female for each dietary treatment varied from 1.5 to 2.3.

As shown by the data presented in Tables 3, 4, and 5, reproductive failure by the females occurred on all diets which contained Lake Michigan coho salmon. No evidence of whelping was observed in 47 of the 53 female mink fed Lake Michigan coho. Only 10 kits were whelped. Of these kits, eight were stillborn and the two that were born alive died within 24 h postpartum. The reproductive performance of the females fed the West Coast coho salmon was not impaired and in many respects was superior to that of mink fed the control rations.

In addition to the adverse effects encountered in feeding Lake Michigan coho salmon to mink, poor reproduction occurred on the rations that

TABLE 3

Reproductive performance of mink fed coho salmon (July 20 – June 30), experiment I

	Fish portion of diet	
	'68 ocean perch (control)	'67 L. Mich. coho salmon
No. females mated	14	8
No. females whelped	13	0[a]
No. kits born:		
alive	48	0
dead	9	0
No. live kits at 4 wk	46	0

[a]One mated female died before whelping.

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contained Lake Michigan bloater chub. Only 58% of the females that received bloater chub in their diet whelped; about 55% of the whelped kits were stillborn. The average size of the litters whelped by females fed the rations that contained Lake Erie coho salmon and Lake Erie or Lake Michigan yellow perch were not greatly reduced.

Mean gestation per dietary group ranged from 47 to 56 days and was not influenced by dietary treatment.

Kit Mortality and Weights

No kits survived longer than 24 h postpartum on diets that contained Lake Michigan coho salmon. Excessive kit mortality (50% or more) was noted on diets that contained Lake Erie coho salmon, Lake Michigan bloater chub, and Lake Michigan yellow perch.

The average birth weight of the kits whelped by females fed the diet that contained Lake Michigan bloater chub was significantly less ($P < 0.05$) than the average birth weight of the kits whelped by females fed the control diet that contained ocean whiting (Table 7). The average weights of 4-week-old kits whelped by females fed diets that contained West Coast coho salmon (Table 6), Lake Erie coho salmon, Lake Michigan bloater chub, and Lake Michigan yellow perch (Table 7) were significantly less ($P < 0.01$) than that of those whelped by females fed the ocean whiting control rations.

Adult Mortality

All mink that received Lake Michigan coho salmon canning by-products in their diet died between the beginning of the breeding season (March 4, 1969) and the end of the whelping period (May 13, 1969). Four females and two males fed the diet which contained Lake Michigan coho salmon in experiment I also died during the latter stages of the feeding trial. Anorexia, bloody stools, fatty livers, and hemorrhagic gastric ulcers were the common symptoms and lesions observed in these mink. Antibiotic treatment and injections of iron; vitamins A, D, and E; and the B-complex vitamins had no beneficial effect in arresting the mortality. Histopathologic examination and bacterial cultures of tissues from these mink failed to reveal the cause of the pathological symptoms.

TABLE 4

Reproductive performance of mink fed various sources of coho salmon (Dec. 10 – June 30), experiment II

	Fish portion of diet				
	'68 ocean whiting (control)	'68 West Coast coho salmon	'67 L. Mich. coho salmon	'68 L. Mich. coho salmon	'68 L. Mich. coho salmon canning by-products
No. females mated	11	12	12	12	11
No. females whelped	10	11	5	0	0
No. kits born:					
alive	38	56	2	0	0
dead	2	7	7	0	0
No. live kits at 4 wk	31	47	0	0	0

TABLE 5

Reproductive performance of mink fed various fish (Jan. 1 – June 30), experiment III

	Fish portion of diet					
	'69 ocean whiting (control)	'69 L. Mich. coho salmon	'69 L. Mich. bloater chub	'69 L. Erie coho salmon	'69 L. Mich. yellow perch	'69 L. Erie yellow perch
No. females mated	12	10[a]	12	12	12	12
No. females whelped	10	1	7	11[b]	10	10
No. kits born:						
alive	45	0	10	32	31	39
dead	10	1	12	17	7	12
No. live kits at 4 wk	29	0	5	7	15	28

[a]Two females died before mating.
[b]One mated female died before whelping.

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TABLE 6

Average body weight of live kits at birth and 4 weeks of age, experiment II

	Fish portion of diet		
	'68 ocean whiting (control)	'68 West Coast coho salmon	'67 L. Mich. coho salmon
At birth			
No. live kits	38	56	2
Body weight in g ± S.E.	9.2±0.38	9.4±0.17	5.3±0.80
At 4 weeks of age			
No. live kits	31	47	0
Body weight in g ± S.E.	162±5.4	138±4.1**	—

**Significantly different than controls ($P < 0.01$) by t test.

TABLE 7

Average body weight of live kits at birth and 4 weeks of age, experiment III

	Fish portion of diet				
	'69 ocean whiting (control)	'69 L. Mich. bloater chub	'69 L. Erie coho salmon	'69 L. Mich. yellow perch	'69 L. Erie yellow perch
At birth					
No. live kits	45	10	32	31	39
Body weight in g ± S.E.	8.2±0.23	7.0±0.59*	7.6±0.20	8.3±0.35	8.2±0.22
At 4 weeks of age					
No. live kits	29	5	2	15	28
Body weight in g ± S.E.	125±3.8	91±13.2**	86±9.3**	104±7.2**	122±3.9

*Significantly different than controls ($P < 0.05$) by t test.
**Significantly different than controls ($P < 0.01$) by t test.

TABLE 8

Peroxide values and mercury content of fish fed to mink in experiment III

Fish	Peroxide value*, meq peroxide/kg fat	Total mercury†, ppm
'69 ocean whiting (control)	165.0	0.08
'69 Lake Michigan coho salmon	36.7	0.30
'69 Lake Michigan bloater chub	6.7	0.10
'69 Lake Erie coho salmon	110.0	0.36
'69 Lake Michigan yellow perch	50.3	0.18
'69 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.

Fish Quality

Peroxide values of the fish fed to the mink in experiment III are shown in Table 8. The peroxide values for the fish ranged from 6.7 to 165.0 meq peroxide per kilogram of 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. The ocean whiting used in the control ration showed the greatest oxidative rancidity of the fish fed to the mink in experiment III, yet it supported the best reproduction and kit growth.

The mercury content of the various fish fed to the mink in experiment III (Table 8) ranged from 0.08 ppm in the ocean whiting (control) to 0.36 ppm 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.

The pesticide residues in the fish and the complete diets are presented in Table 9. The total DDT residue in the fish varied from a high of 18.23 ppm in Lake Michigan coho salmon to a low of 0.64 ppm in ocean whiting. The dieldrin content of the fish ranged from 0.149 ppm in Lake Michigan bloater chub to 0.01 ppm in ocean whiting. A plot of the data on litter size per female mated versus total DDT isomers or dieldrin residue in the fish fed to mink in experiment III indicates that a relationship was evident

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TABLE 9

Pesticide and fat content of the fish and complete diets fed to mink in experiment III*

Fish	Diet	pp'-DDE	op-DDT	pp'-DDD	pp'-DDT	Total DDT	Dieldrin	% fat
'69 Lake Mich. coho salmon		10.12	2.68	1.77	3.66	18.23	0.118	5.8
	30% Lake Mich. coho salmon	1.46	0.28	0.25	0.50	2.49	0.01	5.5
'69 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
'69 Lake Mich. bloater chub		3.87	1.26	0.89	2.79	8.81	0.149	19.8
	30% Lake Mich. bloater chub	0.67	0.31	0.23	0.66	1.87	0.025	8.7
'69 Lake Mich. yellow perch		0.92	0.61	0.70	1.11	3.34	0.061	7.5
	30% Lake Mich. yellow perch	0.16	0.08	0.10	0.14	0.48	0.014	5.3
'69 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
'69 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.

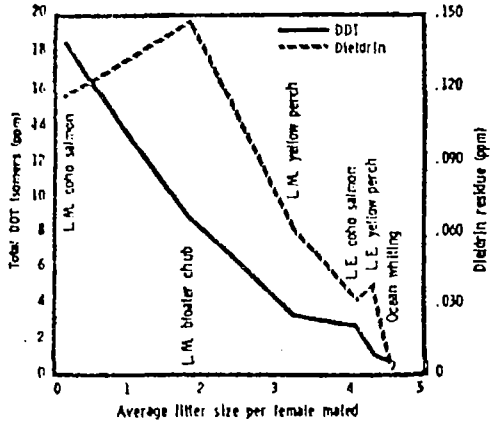

FIG. 1. Relationship between litter size and pesticide residues in fish fed to mink in experiment III.

(Fig. 1). No symptoms of chlorinated hydrocarbon pesticide toxicity such as tremors and loss of coordination were observed.

Discussion

The results of this study indicate that reproductive failure occurs from feeding Lake Michigan coho salmon at 30% of the diet. However, the causative agent does not appear to be the coho salmon per se, nor to be confined to coho salmon. Other species of freshwater fish from the Great Lakes fed to mink at a 30% level also produced adverse reproductive side effects, but differing in degree. More acute reproductive complications occurred in mink that were fed diets which contained fish from Lake Michigan than mink fed rations which contained similar species of fish from Lake Erie or the West Coast. The factor(s) responsible for the reproductive problem was (were) apparently concentrated in the canning by-products (heads, tails, fins, and viscera) of the coho salmon. When the by-product was fed to adult animals at 30% of the diet for about 3 months, it was lethal. The loss of six mink from the group fed Lake Michigan coho salmon during a long-term feeding trial strongly suggests that prolonged feeding of the whole fish, as well as the by-product, is also fatal to adult mink.

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

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isomers or dieldrin) in the fish. If it is assumed that an adult female mink consumes about 150 g of feed per day (Schaible 1970), the total intake of DDT and its metabolites by a whelping female fed the Lake Michigan coho salmon ration over a 4-month period would have been about 45.4 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. Based on the results of other studies (Duby 1970; Aulerich and Ringer 1970; Anon 1970), these levels of DDT and (or) dieldrin residues would apparently not cause reproductive failure to the extent noted in this study. Levels as high as 150 ppm total DDT (commercial grade) fed to mink from weaning through whelping did not impair reproduction (Aulerich and Ringer 1970). The possibility exists, however, that the commercial or technical grades of these pesticides, which are commonly used in pesticide feeding studies, may not be metabolized or affect mink in the same way as comparable levels of naturally occurring pesticide residues. Gilbert (1969) reported poor reproductive performance in female mink and excessive kit mortality on diets which contained lower levels of naturally occurring DDT than those fed in this study.

Perhaps a synergistic action of these chlorinated hydrocarbon pesticides and (or) the presence of other unidentified pesticide residues or contaminants may also have had an important bearing on the problem and should be investigated before definite conclusions are conceived.

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