ENVIRONMENTAL CONTAMINANTS AND PARASITES IN POLAR BEARS

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                                                            and Parasites in Polar
                                                            Bears

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SUMMARY

Tissue samples from polar bears killed by Alaskan based hunters
from 1967 through 1972 were examined for organochlorine hydrocarbons,
PCB's, mercury and *Trichinella* larvae.

Organochlorinated hydrocarbons including the DDT group, hexachlorobenzene,
dieldrin and endrin were at such low levels (less than 0.1 ppm) they
probably have a minimal effect on bears. The mean PCB level in fat was
1.9 ppm. This is a relatively low value compared to levels, apparently
nonlethal, reported in some other mammals. Samples did not show differences
in levels of organochlorinated hydrocarbons or PCB's between age groups
of bears or hunting areas west and north of Alaska.

Polar bears from the west hunting area contained slightly more than
4 micrograms per gram wet weight mercury in liver, and bears from the
north area contained 30 micrograms per gram. Levels in liver were 100-
175 times greater than in muscle. Levels in muscle were below maximum
levels considered safe for human consumption. There is no known industrial
use of mercury in Alaskan polar bear habitat, and food chains may acquire
mercury from a geological source.

Percent incidence of masseter muscle tissue with *Trichinella* larvae
was 64.4, and mean number of larvae per gram in positive samples was
4.15. There was no significant difference in level of incidence or mean
number of larvae per gram between sexes, age groups or west and north
hunting areas.

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BACKGROUND

Polar bears (*Thalarctos maritimus*) are top trophic level consumers which, for the most part, live throughout the year in a restricted sea ice habitat presently far removed from areas where environmental contaminants resulting from human activity enter the ecosystem. Incidence and level of contaminants in polar bears might therefore indicate extent and degree of pollutant dispersion. They might also indicate potential dangers to man, another top level consumer in the Arctic. Human activity in northern regions may increase pollution and, if so, data reported here may serve as baseline information for assessing changes after a number of years of accelerated oil and gas development and related activity, now in their early stages. *Trichinella* is the only parasite commonly found in polar bears. Baseline information on incidence and intensity of infestation may be useful in future studies of natural mortality. Findings also relate to human health because coastal residents eat polar bears and can thereby contract trichinosis, a serious disease in humans. Samples of polar bear tissue for testing for contaminants and parasites were readily available through 1972 when hunting with use of aircraft was permitted. It is unlikely that collections for which data are reported here can ever be duplicated.

OBJECTIVES

To measure incidence and levels of organochlorinated hydrocarbons, PCB's, mercury and *Trichinella* larvae in polar bear tissues.

PROCEDURES

Alaska Department of Fish and Game personnel stationed in coastal villages to monitor hunting of polar bears with aircraft in late February, March and April collected tissue samples from bears killed by hunters from 1967 through 1972.

Specimens came from two hunting areas (Fig. 1). The west area extends from Bering Strait north to 69° N latitude and from a line between Wales and Cape Lisburne west to the Siberian coast. The north area includes sea ice within a 150-mile radius of Point Barrow. A few samples were collected outside these areas and a line extending northwest from Point Lay was arbitrarily chosen as a boundary between them. Recovery of marked animals indicates that bears to the west and bears to the north of Alaska form somewhat discrete subpopulations (Lentfer 1974). Grouping samples by hunting area permitted analyses for differences between these two areas.

An age was assigned to bears based on tooth cementum layers, tooth wear and skull size.

Organochlorine Hydrocarbons and PCB's

Brain and subcutaneous fat tissues were collected in 1970 and subcutaneous fat, skull muscle and liver samples were collected in 1972. To prevent contamination, care was taken that instruments for collecting tissues were clean. Large enough samples were obtained that a small, uncontaminated section could be obtained from the center for analysis. Tissues were wrapped in foil and kept frozen until examined.

WARF Institute, Inc., Madison, Wisconsin, analyzed 25 subcutaneous fat and 25 brain samples obtained from 42 bears in 1970. The first step in the WARF analysis was to weigh a 5- to 20-g portion of the sample in a 150-ml beaker which was then placed in a 40° C oven for 72-96 hours. After drying the sample was weighed back and dry weight calculated. The sample then was ground with Na_2SO_4 (approximately 50 g) and placed in a 33 x 94 mm Whatman extraction thimble. The sample was extracted 8 hours on a soxhlet extractor using 70 ml of ethyl ether and 170 ml of petroleum ether. The solvent was concentrated to 10-15 ml on a steam bath and made to 50 ml with petroleum ether.

For cleanup an aliquot of the sample was placed on previously standardized Florisil (Pesticide Analytical Manual Vol. 1, 1/1/68, Section 211.15). Typical solutions were 150 ml of 5 percent ethyl ether in petroleum ether, followed by 240 ml of 15 percent ethyl ether in petroleum ether. After Florisil the resulting solutions were concentrated on a steam bath (10-15 ml) and made to 25 ml with hexane.

The sample solutions were injected (10 microliters or less) into a gas chromatograph (Barber Colman Pesticide Analyzer Model 5360).

Instrument conditions were:

(1)   Column temperature: 200°C
       Injector temperature: 235°C
       Detector temperature: 240° C
       Column: 4 ft x 4 mm glass packed with 5 percent DC 200 on 80/100
               Gas Chrom. Q.
       Carrier gas: Nitrogen
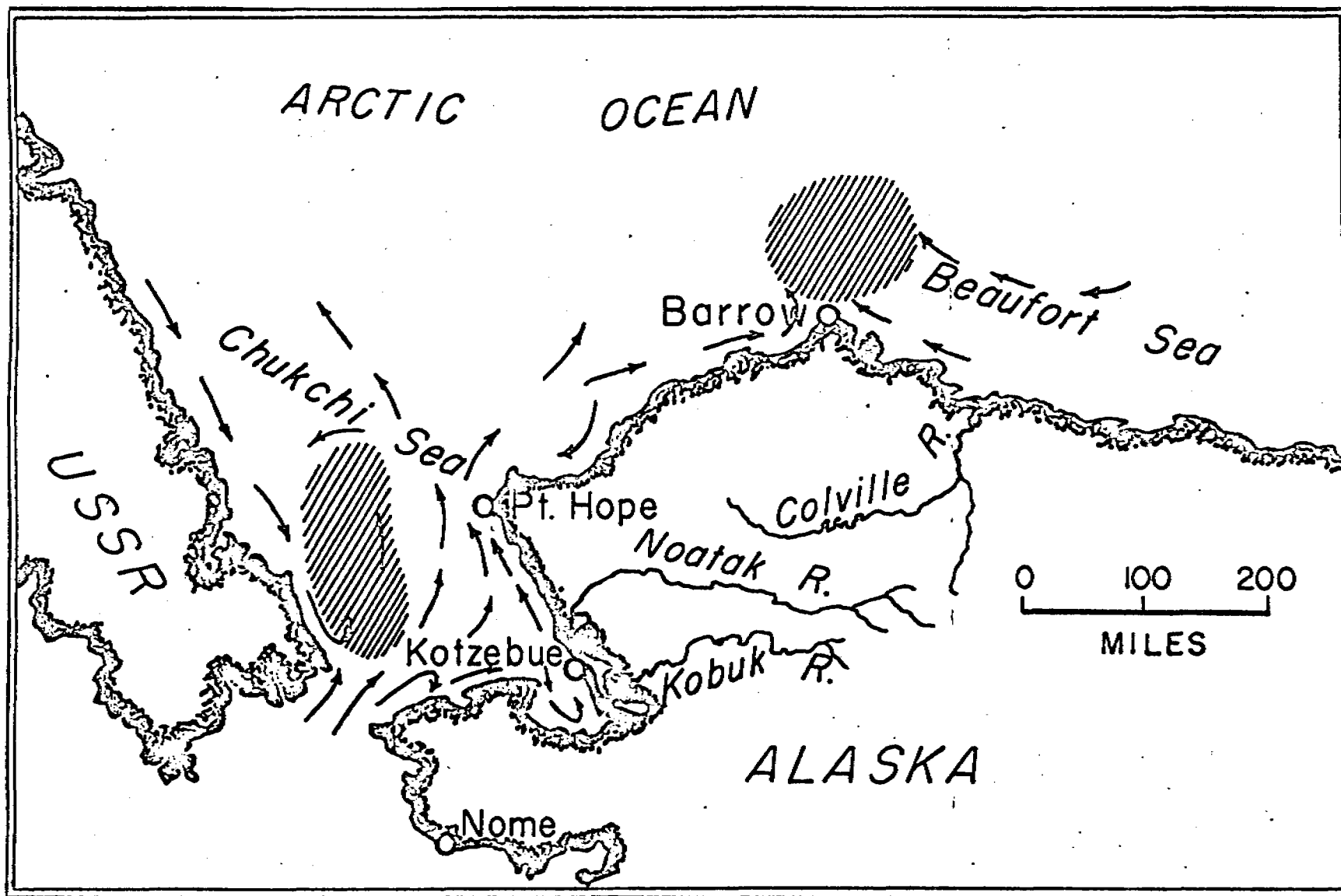   Flow: Such that p,p'-DDT had a retention time of 6-8 minutes.

Fig. 1. Map of northern Alaska and eastern tip of Russia with arrows to indicate direction of ocean currents (from unpublished M.S. thesis by D.C. Burbank, University of Alaska, 1974). Polar bear hunting areas are shaded.

(2) Column temperature: 480°C
     Injector temperature: 235°C
     Detector temperature: 240°C
     Column: 4 ft x 4 mm packed with 3 percent OV-17 on 80.120 mesh Gas
              Chrom. Q.
     Carrier gas: Nitrogen
     Flow: Such that Lindane had a retention time of 2 minutes.

For lipid determination an aliquot of the extract was taken and
placed in a tared 50-ml beaker, reduced to dryness on a steam bath and
placed in a 40° C oven for 2-4 hours. The beaker was removed from the
oven, dessicated, weighed and the amount of lipid in sample calculated.

The U.S. Fish and Wildlife Service Denver Research Center analyzed
74 tissue samples (52 subcutaneous fat, 11 muscle and 11 liver) collected
in 1972 from 27 polar bears killed west of Alaska and 25 bears killed
north of Alaska.

Preparation of fat tissue for extraction consisted of taking aliquots
from various depths and positions within the bulk sample. Aliquots were
melted down and oil produced was decanted into a screw-cap culture tube
and refrigerated until it was extracted. Homogeneity of the aliquot
compound to that of the bulk sample was determined by homogenizing
remaining tissue and then centrifuging the homogenate. Individual oils
produced were treated identically for liquid-liquid partition, Florisil
column cleanup, separation and gas chromatograph analysis. In comparing
results no discrepancy in residue level was detected; consequently it
was unnecessary to use an entire fat sample. Preparation of liver and
muscle tissue consisted of homogenizing the entire sample with a Hobart
grinder prior to extraction and partition.

Exactly 0.5 g of fat (oil) was placed in a 250-ml separatory funnel
with 60 ml hexane saturated acetonitrile. The separatory funnel was
then shaken vigorously for 1 minute. After the phases had separated,
the acetonitrile phase was drained into a 1-liter separatory funnel.
The hexane layer was partitioned two more times with 60 ml hexane saturated
acetonitrile. To the combined acetonitrile layers, 250 ml of distilled
water, 50 ml of 5 percent (w/v) sodium sulfate solution and 150 ml of
hexane were added. The separatory funnel was then shaken vigorously for
1 minute. After the phases had separated, the water-acetonitrile layer
was discarded. The hexane layer was washed with 100 ml of sodium sulfate
solution. This solution was also discarded.

For liver and muscle exactly 10 g of homogenized tissue was combined
with 50 g of granular anhydrous sodium sulfate. The mixture was frozen
and then blended until it was thoroughly homogenized. The sample-sodium
sulfate mixture was then quantitatively transferred to a glass-stoppered
flask along with 100 ml 20 percent (v/v) acetone/isooctane.

The flask was then shaken at medium speed for 30 minutes on a wrist
action shaker. After the sample-sodium sulfate mixture had settled, a
portion of the solvent layer was removed, partitioned with an equal
volume of distilled water and centrifuged. An aliquot of the clear
isooctane layer was then taken for Florisil column cleanup and component
separation.

Exactly 5.0 g of Florisil (60-100 mesh) which had been factory activated at 1250° F and stored in an oven at 130° C was placed in a 12 X 60 mm chromatographic column. The column was equipped with a 125 ml reservoir and bottom glass frit. The column was tapped on a bench top until the Florisil had completely settled. A 0.5 in. bed of granular anhydrous sodium sulfate was then added over the Florisil. The column was then immediately pre-eluted with 40 ml of hexane. When the last of the hexane had sunk to the top of the sodium sulfate, 3.0 ml of sample extract was placed on the column. When the sample extract had sunk to the top of the sodium sulfate, 75 ml of hexane was added. The sample-hexane eluate was collected in a K-D and followed by a second separately collected eluate of 100 ml of 10 percent (v/v) acetone-hexane.

The eluates were concentrated over a steam bath in their respective K-D's and subsequently subjected to gas chromatography for qualitative and quantitative residue determination. Instrumentation included a Varian 2740 gas chromatograph, tritium electron-capture detector. Column dimensions were 6 ft x 2 mm I.D. and column packings consisted of 3 percent OV-1 on 80/100 mesh chromosorb W, AW, DMCS and 5 percent QF-1 on 100/120 mesh chromosorb W, AW, DMCS. Other instrumentation was a Nuclide 1290-G single focussing magnetic mass spectrometer coupled with a Varian 200 gas chromatograph. Column was a 100 ft x 0.03 in. I.D. capillary column coated with OV-101.

The accuracy and precision of the entire analytical procedure were determined for fat tissue before the actual analyses of samples began and were also checked periodically during analyses.

Initial determinations were made by splitting one sample into four aliquots and overspiking each aliquot with heptachlor epoxide, DDE, DDD, DDT, dieldrin and endrin. The percent variations and percent recoveries were: heptachlor epoxide - 4.9 percent and 106 percent; DDE - 12 percent and 79 percent; DDD - 7.7 percent and 62 percent; DDT - 14 percent and 61 percent; dieldrin - 12 percent and 96 percent and endrin - 3.6 percent and 67 percent. Results as reported have not been corrected for accuracy.

Periodic determinations of the reproducibility of the entire procedure were achieved by splitting six fat samples and running them as duplicates. The percent variation was statistically determined on samples which contained Aroclor 1260, hexachlorobenzene (HCB), DDE and dieldrin. Variations were: Aroclor 1260 - 13 percent, HCB - 0.02 percent, DDE - 5 percent and dieldrin - 2 percent. These were the only components common to all six samples. In addition to these determinations, every tenth sample was duplicated as a further check of precision.

Preparation and extraction of liver and muscle tissue were by procedures routinely used in the Denver laboratory. Consequently, determinations on accuracy and precision were not made.

Since laboratory contamination is always a possibility, blanks were frequently run to check the quality of analyses. All blanks were free of laboratory contamination.

Utilizing a Florisil column cleanup and separation of sample residues into two eluates allowed quantification down to 0.1 ppm for PCB's and 0.01 ppm for chlorinated pesticides in liver, muscle and fat tissue. The first eluate contained HCB, gammachlordane, DDE and Aroclor 1260, and the second eluate contained heptachlor epoxide, DDD, DDT, dieldrin and endrin. Aroclor 1260 did not significantly interfere in the quantification of HCB or DDE.

All residues were identified and quantified through the use of two dissimilar gas chromatographic columns. In addition, HCB, DDE, chlordane and one isomer of Aroclor 1260 were confirmed by gas chromatograph mass spectometry. In addition to confirmation by two dissimilar gas chromatographic columns, dieldrin was treated with fuming sulfuric for further confirmation. The peak in the chromatogram with a retention time, on two dissimilar columns, corresponding to dieldrin was not detected after treatment with fuming sulfuric.

Mercury

Masseter muscle and liver tissue samples collected from polar bears in 1972 were wrapped in aluminum foil, sealed in plastic bags and kept frozen until analyzed during the following 6 months by W.A. Galster, Institute of Arctic Biology, University of Alaska. These included 25 liver and 16 muscle samples from the west hunting area and 38 liver and 30 muscle samples from the north hunting area. Tissues were digested overnight under reflux conditions in a mixture of three parts nitric acid and one part sulfuric acid. They were analyzed by flameless atomic absorption (Hatch and Ott 1968) using a long (22 cm) vapor chamber for increased sensitivity. Permanganate and cadmium were added to the digest and reducing agent, respectively, to assure assessment of all mercury in tissue (Armstrong and Uthe 1971, Magos and Clarkson 1972). As a check, mercury levels in three samples were also determined by neutron activation. Results were similar to those obtained by flameless atomic absorption.

Trichinella

Masseter muscle samples collected from polar bear skulls during four hunting seasons (1967-70) included 131 specimens from the west area and 161 specimens from the north area. Specimens were kept frozen until examined, 1-6 months later, by Richard Barrett of the State-Federal Laboratory in Palmer, Alaska.

Samples were artificially digested to determine presence of *Trichinella* larvae. Partially frozen samples were individually chopped into small pieces and 10 g of each sample placed in a solution of 0.6 percent pepsin and 0.4 percent hydrochloric acid. Samples were incubated at 37° C for 18-24 hours with agitation the first 6-8 hours. The resulting digest was transferred to sedimentation glasses and allowed to stand while larvae and particulate matter settled out. Supernatant was discarded and larvae counted under a dissecting mircroscope.

FINDINGS AND DISCUSSION

Organochlorine Hydrocarbons and PCB's

Samples from 1970 were analyzed without pre-separation of PCB's from other residues (Table 1). Without pre-separation, PCB's interfere with determination of levels of other residues (Reynolds 1969), and other residues (mostly chlorinated insecticides) interfere with determination of PCB levels (F.B. Coon, WARF Institute, pers. comm.). Therefore, values in Table 1 must be considered estimates. Because quantification of 1970 samples was so imprecise and because PCB's can be pre-separated from other residues, samples from 1972 were pre-separated (Table 2). Fat is the only tissue which was analyzed for both years and therefore both with and without separation, and results are strikingly different, especially for PCB's. Levels after pre-separation are judged to be closer to true values and Table 2 will be the basis for most of the following discussion.

Residues accumulate in fat and fat samples contained much higher levels than liver or muscle. Organochlorinated hydrocarbon and PCB residues were identified in most samples of fat tissue. Samples were grouped to provide a comparison between west and north hunting areas as a possible indicator of subpopulation differences and to provide a comparison between mature and immature animals. With the small number of samples there were no apparent differences between hunting areas or between age groups. A possible exception was that the only endrin measured was for 3 of 15 fat samples from mature animals from the west area.

Organochlorinated hydrocarbons, including the DDT group, hexachlorobenzene, dieldrin and endrin, were at such low levels (less than 0.1 ppm) they probably have a minimal effect on bears.

There is a limited amount of earlier work for comparison. Durham et al. (1961) analyzed foods of Alaska Natives in rural areas for DDT and DDE using a modified Schechter-Holler spectophotometric procedure. Foods included polar bear, seal, walrus, whale, caribou, eider duck and snowy owl. The only residue detected was 1.1 ppm DDE in the meat of two snowy owls.

PCB's were at higher levels (mean of 1.9 ppm in fat tissue) than other residues. PCB's are stable compounds with a variety of industrial uses. They are manufactured in several counties and enter the ecosystem by incineration, runoff from industrial wastes and dumps and from plants where manufactured and where processed into other products. PCB's, along with DDE and in quantities similar to DDE, are perhaps the most widespread of global pollutants. Their high lipid solubility causes them to collect in fatty tissues of lower animals and marine life. Therefore, species at the top of a food chain will accumulate PCB's, particularly in lipid tissue and liver, in much the same way they accumulate DDT and other chlorinated pesticides (Gustafson 1970).

Table 1. Chlorinated hydrocarbons and PCB's in Alaskan polar bear tissues, 1970 1/

	DDE	DDD	DDT	Dieldrin	Benzene Hexachloride	PCB's
WEST AREA						
Immature Bears (1-5 yrs)						
No. fat samples	2	2	2	2	2	2
No. with residue	2	2	2	2	2	2
Ave. accumulation 2/	.12	.21	.43	.27	.89	25.40
Std. dev.	.04	.01	.09	.26	.01	3.39
Percent lipid	78.3	78.3	78.3	78.3	78.3	78.3
No. brain samples	1	1	1	1	1	1
No. with residue	1	1	1	1	1	1
Ave. accumulation	.02	.03	.02	0	.29	.33
Std. dev.	--	--	--	--	--	--
Percent lipid	13.1	13.1	13.1	13.1	13.1	13.1
Mature Bears (6 yrs +)						
No. fat samples	10	10	10	10	10	10
No. with residue	10	10	10	9	9	10
Ave. accumulation	.08	.17	.25	.10	.54	10.65
Std. dev.	.03	.06	.07	.03	.31	5.37
Percent lipid	81.8	81.8	81.8	81.4	81.4	81.8
No. brain samples	12	12	12	12	12	12
No. with residue	10	12	12	6	12	12
Ave. accumulation	.02	.02	.02	.02	.14	.27
Std. dev.	.01	.01	.01	.02	.04	.08
Percent lipid	14.9	15.2	15.2	14.2	15.2	15.2
NORTH AREA						
Immature Bears (1-5 yrs)						
No. fat samples	3	3	3	3	3	3
No. with residue	3	3	3	3	3	3
Ave. accumulation	.15	.25	.52	.07	.53	20.02
Std. dev.	.07	.12	.28	.01	.03	9.86
Percent lipid	83.5	83.5	83.5	83.5	83.5	83.5
No. brain samples	4	4	4	4	4	4
No. with residue	3	4	4	1	4	4
Ave. accumulation	.01	.01	.01	.01	.16	.25
Std. dev.	.001	.003	.001	--	.05	.05
Percent lipid	11.8	12.6	12.6	15.2	12.6	12.6
Mature Bears (6 yrs +)						
No. fat samples	10	10	10	10	10	10
No. with residue	10	10	10	10	10	10
Ave. accumulation	.13	.19	.41	.08	.34	15.07
Std. dev.	.04	.08	.14	.05	.16	4.39
Percent lipid	87.1	87.1	87.1	87.1	87.1	87.1
No. brain samples	8	8	8	8	8	8
No. with residue	7	7	8	3	8	8
Ave. accumulation	.01	.02	.02	.01	.11	.25
Std. dev.	.01	.01	.01	.01	.06	.22
Percent lipid	14.1	14.3	14.3	15.1	14.3	14.3

1/ Analysis by WARF Institute without pre-separation of chlorinated hydrocarbons and PCB's

2/ Averages include only those samples which had measureable amounts of residue. Averages are in ppm wet weight of whole sample, i.e., both lipid and non-lipid portions.

Table 2. Chlorinated hydrocarbons and PCB's in Alaskan polar bear tissues, 1972 [1]

	Hexachloro-benzene	DDE	DDD	DDT	Dieldrin	Endrin	Heptachlor Epoxide	PCB's
WEST AREA								
Immature Bears (1-5 yrs)								
No. fat samples	10	10	10	10	10	10	10	10
No. with residue	10	10	0	4	10	0	7	10
Ave. accumulation [2]	.07	.05	--	.09	.08	--	.04	1.7
Std. dev.	.02	.03	--	.07	.02	--	.03	.94
No. liver samples	2	2	2	2	2	2	2	2
No. with residue	0	0	2	0	0	0	0	1
Ave. accumulation	--	--	.17	--	--	--	--	.4
Std. dev.	--	--	.16	--	--	--	--	--
No. muscle samples	2	2	2	2	2	2	2	2
No. with residue	0	0	0	0	0	0	0	0
Mature Bears (6 yrs +)								
No. fat samples	15	15	15	15	15	15	15	15
No. with residue	15	15	0	11	15	3	8	15
Ave. accumulation	.06	.04	--	.12	.13	.11	.03	2.0
Std. dev.	.02	.02	--	.05	.06	.06	.01	.80
No. liver samples	2	2	2	2	2	2	2	2
No. with residue	0	0	3	0	0	0	0	2
Ave. accumulation	--	--	.21	--	--	--	--	.3
Std. dev.	--	--	.27	--	--	--	--	.14
No. muscle samples	2	2	2	2	2	2	2	2
No. with residue	0	0	0	0	0	0	0	0
NORTH AREA								
Immature Bears (1-5 yrs)								
No. fat samples	13	13	13	13	13	13	13	13
No. with residue	13	13	0	6	13	0	6	13
Ave. accumulation	.07	.05	--	.06	.09	--	.03	1.9
Std. dev.	.03	.02	--	.03	.06	--	.01	.71
No. liver samples	2	2	2	2	2	2	2	2
No. with residue	0	0	2	0	0	0	0	2
Ave. accumulation	--	--	.04	--	--	--	--	.3
Std. dev.	--	--	.0	--	--	--	--	.07
No. muscle samples	2	2	2	2	2	2	2	2
No. with residue	0	0	0	0	0	0	0	0
Mature Bears (6 yrs +)								
No. fat samples	14	14	14	14	14	14	14	14
No. with residue	14	14	0	6	14	0	8	14
Ave. accumulation	.06	.06	--	.04	.07	--	.02	2.1
Std. dev.	.03	.03	--	.02	.03	--	.02	.75
No. liver samples	3	3	3	3	3	3	3	3
No. with residue	0	0	2	0	0	0	0	3
Ave. accumulation	--	--	.13	--	--	--	--	.6
Std. dev.	--	--	.04	--	--	--	--	.38
No. muscle samples	3	3	3	3	3	3	3	3
No. with residue	0	0	0	0	0	0	0	0

[1] Analysis by U.S. Fish and Wildlife Service Denver Research Center.

[2] Averages include only those samples which had measureable amounts of residue. Fat samples are in ppm lipid wet weight. Liver and muscle samples are in ppm wet weight.

In the United States PCB's are designated as Aroclors, each of which has a number to identify its specific formula. The four most common Aroclors found in the environment are 1242, 1248, 1254 and 1260. As they move in the environment and move up in the food chain, they are subjected to physical decomposition and chemical metabolism which often cause the resulting residue to most closely resemble Aroclor 1254 on the gas chromatograph (F.B. Coon, WARF Institute, pers. comm.). For the 1970 samples the gas chromatographic pattern seemed to best fit Aroclor 1254 and results were calculated from a sample of technical Aroclor 1254 used as a sample. For the 1972 samples the gas chromatographic pattern seemed to best fit Aroclor 1260, which was therefore used as a standard. Results calculated from standards are not necessarily the same as residues in tissues and must be considered estimates. However, they are probably adequate to give an indication of biological significance (Peakall and Lincer 1970).

PCB patterns in 1970 samples were quite different from any noted by WARF Institute previously, possibly because polar bears are quite far removed from the source of use of most PCB's. This could cause more weathering and possibly more passes through biological systems, which could cause changes in the PCB patterns (F.B. Coon, pers. Comm.).

Peakall and Lincer (1970) stated that, as with the chlorinated hydrocarbon pesticides, the most important effects of PCB's are long-range sublethal effects. Their summary of findings of others showed that the liver is the organ most often affected in mammals. There is little published information on levels of PCB's which are lethal to mammals. However, levels in Alaskan polar bears are lower than levels reported in several other marine mammals (Summary by Stickel 1973, pp. 292-294; Frank et al. 1973). Because there was no discussion of these higher levels in other marine mammals being lethal and because many of these samples were from "normal" appearing animals taken in commercial harvests, it is assumed that the lower levels in Alaskan polar bears are not lethal. More mammal studies including experimental studies of long-term effects of low-level exposure to PCB's are needed, however. Studies of hibernators which, during hibernation, utilize fat reserves where PCB's accumulate would be of special significance for polar bears.

Stickel (1972) presents information that may be relevant for polar bears. Shrimp are very sensitive to PCB's and most will die from a 20-day exposure to a concentration of 5 ppb. Growth of certain marine diatoms was experimentally inhibited by PCB's. The small marine crustacean, *Gammarus*, is sensitive to PCB's in concentrations of thousandths to tenths of a part per billion. PCB's could therefore concievably affect lower trophic levels of the Arctic marine food chain.

Mercury

A Student's "t" test did not reveal significant differences at the 0.05 probability level in mean levels of mercury in male and female polar bears, therefore, results from males and females were combined (Table 3 and Figs. 2 and 3). West area samples contained 98 times more mercury in liver than in meat and north area samples contained 178 times more mercury in liver than in meat. North area samples contained seven times more mercury in liver and four times more mercury in muscle than west area samples. Differences are not attributed to the difference in mean age of bears sampled from the two areas. Bears from the Beaufort Sea appeared to accumulate mercury in liver tissue four times faster than bears from the Chukchi Sea but this accumulation was not evident in muscle tissue of either group.

The difference in accumulation of mercury supports the concept of different subpopulations of bears west and north of Alaska (Manning 1971, Lentfer 1974, Wilson in press). Larger accumulations in livers of bears from the north area (Fig. 2) suggest the food chain in this region carries a greater burden of mercury than the west area. It is also possible that levels in the ocean are about the same in each area but that ringed seals (*Phoca hispida*), the primary food of bears, carry different levels because their diets differ in the two areas (John Burns, Alaska Department of Fish and Game, Fairbanks, pers. comm.).

Mercury is present in ringed seals, the main food of polar bears, but at lower levels than in bears. Galster (1971) reported the following average mercury concentrations (wet weight) in combined samples of ringed seal tissues from the Nome and Barrow areas: liver - 1.254 micrograms per gram $\pm$ 3.10 S.E., N = 21; kidney - 1.529 micrograms per gram $\pm$ 0.791 S.E., N = 15 and muscle - 0.141 microgram per gram $\pm$ 0.24 S.E., N = 12. He did not report levels in seal fat which provides most of the food for bears.

The source of mercury in the Chukchi and Beaufort Seas and the reason for higher levels in the Beaufort Sea are not adequately understood. There is no industrial use of mercury or other human activity which would release mercury into the environment in the Chukchi and Beaufort areas. Recent surveys have not revealed any unusual concentrations in these areas (H.V. Weiss, Naval Undersea Research and Development Center, San Diego, California, pers. comm.). The nearest reported accumulation of mercury is sediments of the Seward Peninsula (Nelson et al. 1972). Possibly this could contribute some mercury to the Chukchi and Beaufort Seas by water transport and animal migrations. Another possible source is from the atmosphere which may be receiving mercury from degassing of the earth's crust and certain actions of man (Weiss et al. 1971). W.A. Galster (Institute of Arctic Biology, University of Alaska, Fairbanks, pers. comm.) suggests that possibly the Beaufort Sea has higher levels than the Chukchi Sea because of a geologic source in the deep ocean bottom of the Beaufort Sea.

Table 3. Accumulations of mercury in Alaskan polar bear tissues, 1972.

| | Tissue | | Age of |
	Liver	Muscle	Bears
West Area			
No. samples	25	16	12
Mean *	4.235	.043	3.8
Std. Dev.	1.385	.001	1.2
North Area			
No. samples	38	30	38
Mean	29.914	.168	5.7
Std. Dev.	22.547	.089	3.5

* Micrograms per gram wet weight.
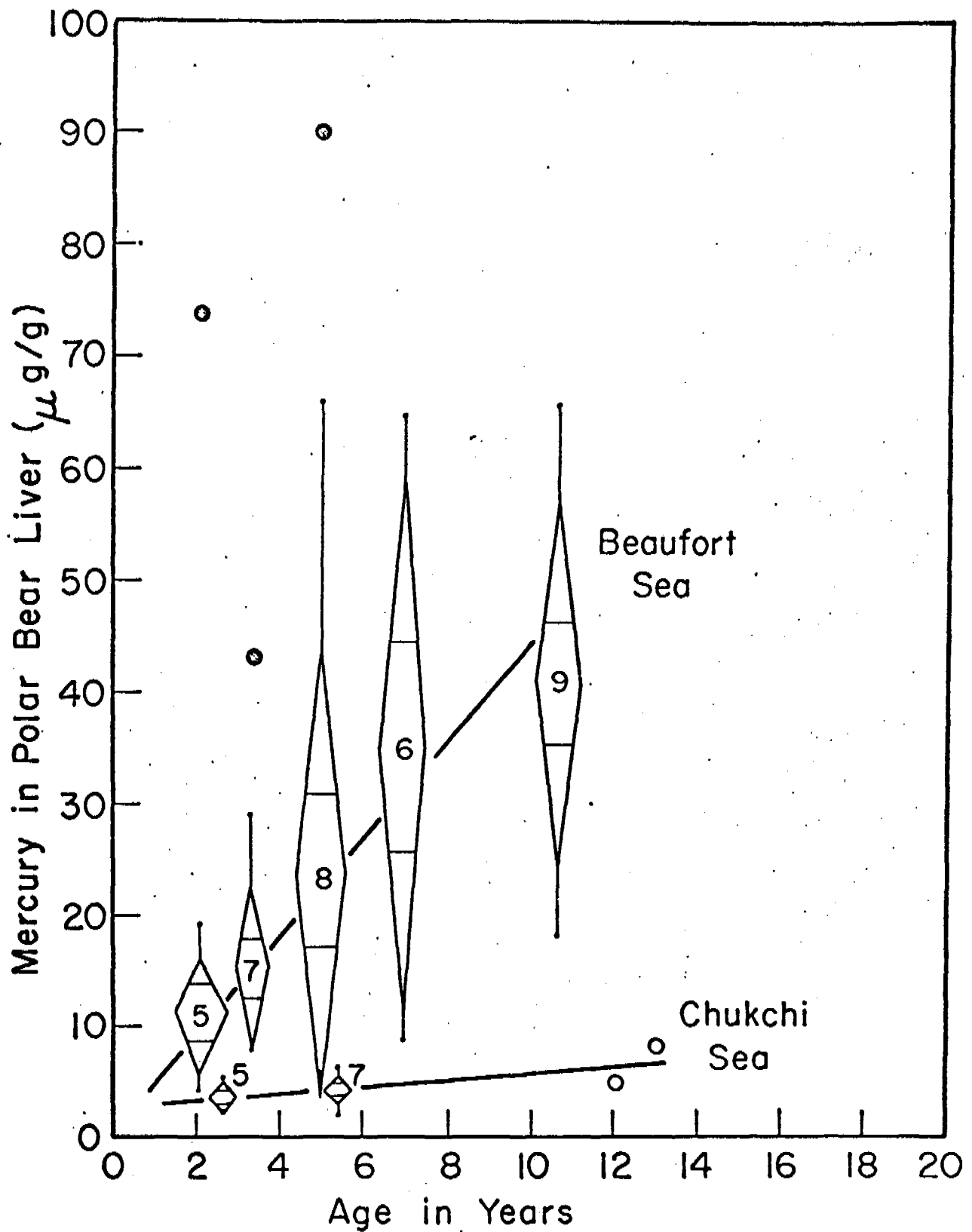
Fig. 2. Comparison of the accumulation of mercury in livers of polar bears from
the west hunting area (Chukchi Sea) and north hunting area (Beaufort Sea).
Mean, standard error, standard deviation and sample size given for age
groups excluding 3 points found more than 3 standard deviations from the
mean.
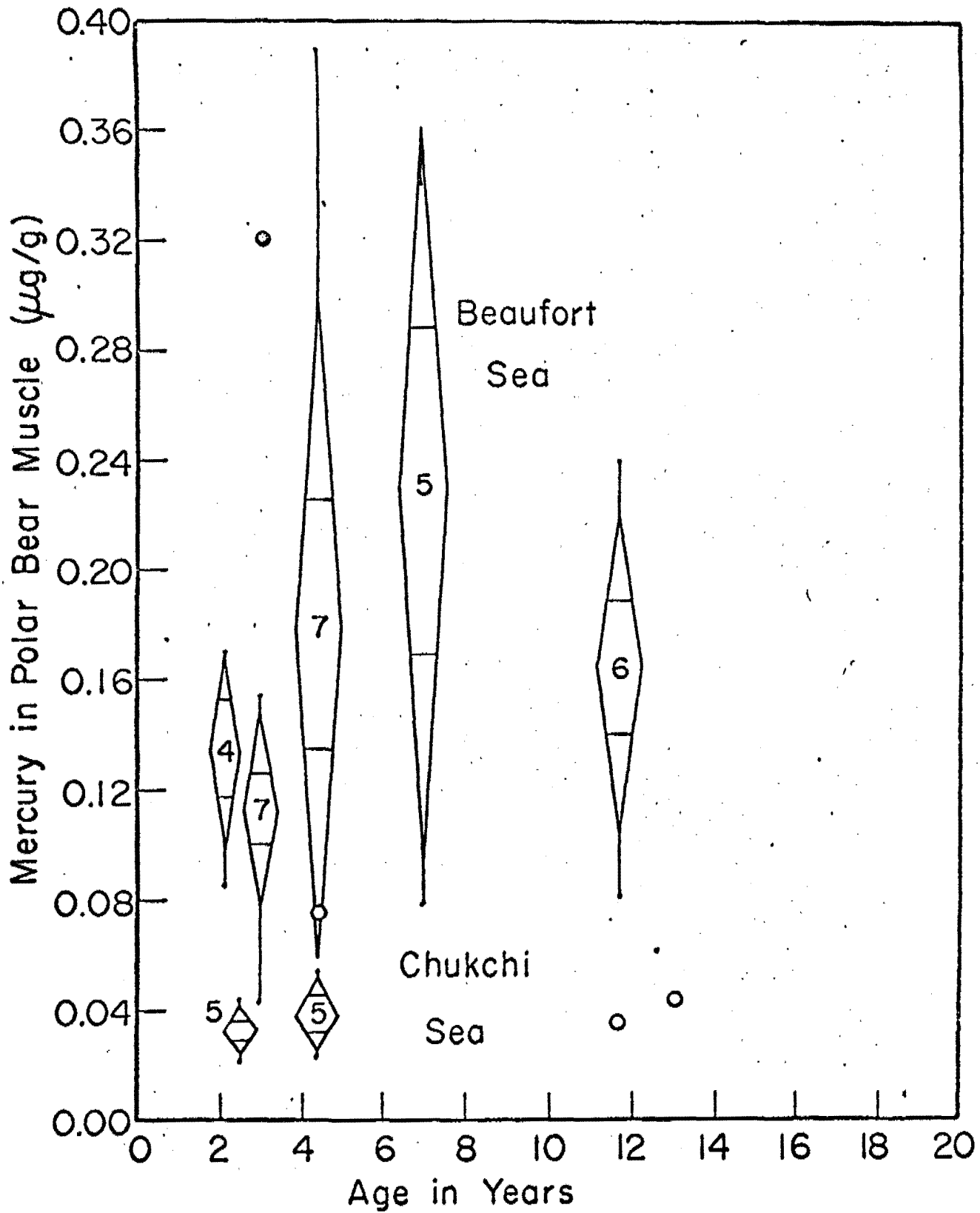
Fig. 3. Comparison of the accumulation of mercury in muscles of polar bears from the west hunting area (Chukchi Sea) and north hunting area (Beaufort Sea). Mean, standard error, standard deviation and sample size given for age groups excluding 3 points found more that 3 standard deviations from the mean.

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Eskimos living along the Arctic coast also utilize seals for food
and might be expected to accumulate mercury as do polar bears. Blood of
Canadian Eskimos from coastal villages contained higher levels of mercury
than blood from residents of interior Canadian villages (Environment
Research Consultants, Ltd. 1973). In the present study, mercury in
polar bear muscle in the high-level north area (0.17 microgram per gram)
is well below the 0.5 microgram per gram considered safe for human
consumption (U.S. Food and Drug Administration, Seattle, Washington,
pers. comm.). Muscle is the only polar bear tissue normally eaten by
humans. Eskimos do not eat liver, where mercury accumulates, because of
toxic levels of vitamin A.

Trichinella

Of 292 masseter muscle samples examined, 64.4 percent contained
Trichinella larvae. The mean number of larvae per gram in 144 samples
was 4.15 (Table 4). Nine samples had extremely high larvae per gram
values ranging from 33.0 to 75.0. They were not confined to any one
area, sex or age class and were arbitrarily omitted to reduce variance
when computing means in Table 4. Table 4 suggests that the incidence of
occurrence of Trichinella larvae in polar bears may increase with age.
However, a Chi-square test to compare observed frequencies of occurrence
with expected frequencies based on mean frequency for all bears, indicated
no significant difference in incidence of occurrence among age groups at
the 0.05 level. For a comparison of three age groups (1-4 years, 5-8
years and 9 years and older) of a pooled sample of all bears, Chi-square
was 2.2 with 2 degrees of freedom. For the north area, which had the
greatest difference among age groups, Chi-square was 4.63 with 2 d.f.
There were no obvious differences in the mean number of larvae per gram
between any sub-groups. A Student's "t" test revealed no significant
differences in mean number of larvae for the following: all bears from
west area compared with all bears from north area ("t" = 0.70 with 142
d.f.); all males compared with all females ("t" = 1.01 with 142 d.f.) or
all bears 1-4 years old compared with all bears older than 8 years ("t"
= 0.92 with 87 d.f.).

Trichinella larvae have been reported in polar bears in other
sections of the Arctic (Table 5). Sample sizes were smaller than in
this study, and incidence in most cases was lower.

The method of transmission of Trichinella among Arctic animals is
of interest. Rausch et al. (1965) stated that "Conditions in Arctic
regions are particularly favorable for the transmission of Trichinella
larvae among wild mammals. Mammals are abundant although the number of
species represented is relatively small. A large proportion of the
species present is comprised of those which are entirely or occasionally
carnivorous and predator-prey relationships are in general well defined."
Cameron (1950), Rausch et al. (1956) and Ozeretskoyskaya et al. (1969)
concluded that Trichinella is endemic in wild mammals in the Arctic and
has not been introduced by man in recent years.

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Table 4. Incidence and intensity of *Trichinella* larvae in polar bear masseter muscle, Alaska, 1967-70.

Area, Sex, and Age	Incidence			Larvae per Gram		
	No. Examined	No. Positive	Percent Positive	No. Positive Samples Examined	Mean Larvae Per Gram	Std. Dev.
West Area						
Male						
1-4	31	19	61.3	18	5.23	5.97
5-8	54	33	61.1	23	3.82	5.81
9 & older	19	12	63.2	9	2.31	3.60
Total	104	64	61.5	50	4.05	5.54
Female						
1-4	25	17	68.0	15	3.29	4.14
5-8	2	2	100.0	2	1.60	.71
9 & older	0	--	--	--	--	--
Total	27	19	70.4	17	3.09	3.91
Both Sexes						
1-4	56	36	64.3	33	4.35	5.23
5-8	56	35	62.5	25	3.64	5.60
9 & older	19	12	63.2	9	2.31	3.60
Total	131	83	63.4	67	3.81	5.17
North Area						
Male						
1-4	38	24	63.2	19	4.82	5.39
5-8	45	34	75.6	24	5.21	5.89
9 & older	16	15	93.8	13	3.74	5.28
Total	99	73	73.7	56	4.74	5.52
Female						
1-4	55	26	47.3	17	3.84	6.19
5-8	6	6	100.0	4	2.93	1.68
9 & older	1	0	0	0	--	--
Total	62	32	51.6	21	3.66	5.59
Both Sexes						
1-4	93	50	53.8	36	4.36	5.72
5-8	51	40	78.4	28	4.89	5.53
9 & older	17	15	88.2	13	3.74	5.28
Total	161	105	65.2	77	4.44	5.52

Table 4. - Continued.

Area, Sex, and Age	Incidence			Larvae per Gram		
	No. Examined	No. Positive	Percent Positive	No. Positive Samples Examined	Mean Larvae Per Gram	Std. Dev.
West and North Areas						
Male						
1-4	69	43	62.3	37	5.02	5.60
5-8	99	67	67.7	47	4.53	5.83
9 & older	35	27	77.1	22	3.16	4.63
Total	203	137	67.5	106	4.42	5.51
Female						
1-4	80	43	53.8	32	3.58	5.25
5-8	8	8	100.0	6	2.48	1.50
9 & older	1	0	0	0	--	--
Total	89	51	57.3	38	3.41	4.86
Both Sexes						
1-4	149	86	57.7	69	4.35	5.45
5-8	107	75	70.1	53	4.30	5.54
9 & older	36	27	75.0	22	3.16	4.63
Total	292	188	64.4	144	4.15	5.35

Table 5. Incidence of *Trichinella* reported in polar bears by other workers.

Location	No. of Bears Examined	No. Positive	Authority
Alaska	17	9	Rausch et al. 1956
Franz-Joseph Land, Russia	7	7	Brown et al. 1949
Franz-Joseph Land, Russia	4	2	Ozeretskoyskaya et al. 1969
East Greenland	13	4	Thorborg et al. 1948
Greenland	112	31	Summary in Roth 1950
West Greenland	19	6	Roth 1949
Thule Region, Greenland	3	2	Thorborg et al. 1948
Northwest Territories, Canada	3	2	Brown et al. 1949

Ringed seals and to a lesser extent bearded seals (*Erignathus barbatus*) may serve as a primary source of *Trichinella* larvae for Alaskan polar bears. Rausch et al. (1956) reported *Trichinella* larvae in 2 of 310 seals examined from Arctic Alaska. All seals were not specifically identified but most were ringed seals and harbor seals (*Phoca vitulina*) and a few were ribbon seals (*Histriophoca fasciata*). Rausch et al. (1956) also reported one of the 128 Alaskan bearded seals to be infected. Roth (1950) found one of 52 ringed seals in west Greenland to be infected. While these levels are not high it is quite possible than any individual bear which feeds almost exclusively on ringed and bearded seals would eventually become infected. The method of transmission of larvae to ringed and bearded seals is also of interest, especially because these seals ordinarily feed on fishes and invertebrates in which *Trichinella* is incapable of developing. Vibe (1950) suggested that seals ingest larvae in bits of meat accidently swallowed while seals are feeding on amphipods which are feeding on carcasses of infested mammals. Fay (1968) demonstrated that larvae could also be transmitted in the undigested contents of the alimentary tract of amphipods and thought this might be more probable than by direct ingestion of meat.

Trichinosis in man, from polar bears, has been reported in western Alaska (Williams 1946), the DeLong Islands (Ozeretskoyskaya and Uspensky 1957 cited in Ozeretskoyskaya et al. 1969), Franz Joseph Land (Arctic Institute of North America 1948) and Barents Sea, Siberia (Golenko 1963 cited in Ozeretskoyskaya et al. 1969). Present day Alaskan Eskimos in areas where polar bears are eaten are aware of trichinosis in a general way and thoroughly cook polar bear meat before eating it.

RECOMMENDATIONS

Levels of organochlorinated hydrocarbons and PCB's in polar bears should be measured again in about 10 years. Results could reflect changes caused by a reduced use of these substances and by increasing human activity in the Arctic. Any future program should include analysis of brain tissue, if possible, as recommended by Stickel (1973). If too few animals are being taken to provide an adequate sample of tissues, fat specimens could be obtained by excising from beneath the skin of animals immobilized for other studies. Present Bureau of Land Management outer continental shelf studies should include determining levels of organochlorinated hydrocarbons and PCB's in the Arctic marine food chain and effects to Arctic marine organisms of long-term low-level exposure. As studies of organochlorinated hydrocarbons and PCB's in hibernating animals are completed, they should be reviewed to determine if findings have application for polar bears.

Mercury levels in polar bears should be checked again in about 10 years. Levels in the Arctic marine food chain could be checked now as part of the Bureau of Land Management's outer continental shelf studies. Aliquots from the present study should be preserved to provide levels of other heavy metals for comparison should other metals become recognized as serious contaminants in the future.

Trichinella larvae occur naturally in the Arctic, and man's future activities may not have much effect on levels or incidence of infestation in polar bears. Bears found dead from natural causes should be examined for Trichinella as a possible cause of mortality.

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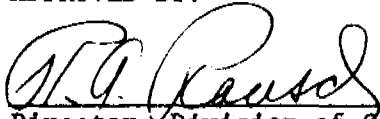sheet: evidence of recent input by man. Science. 174:692-694.

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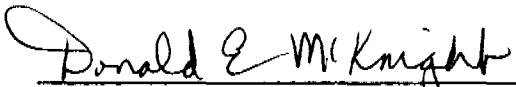Conf. on bear research and management. Binghamton, New York. 31 May-1 June
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