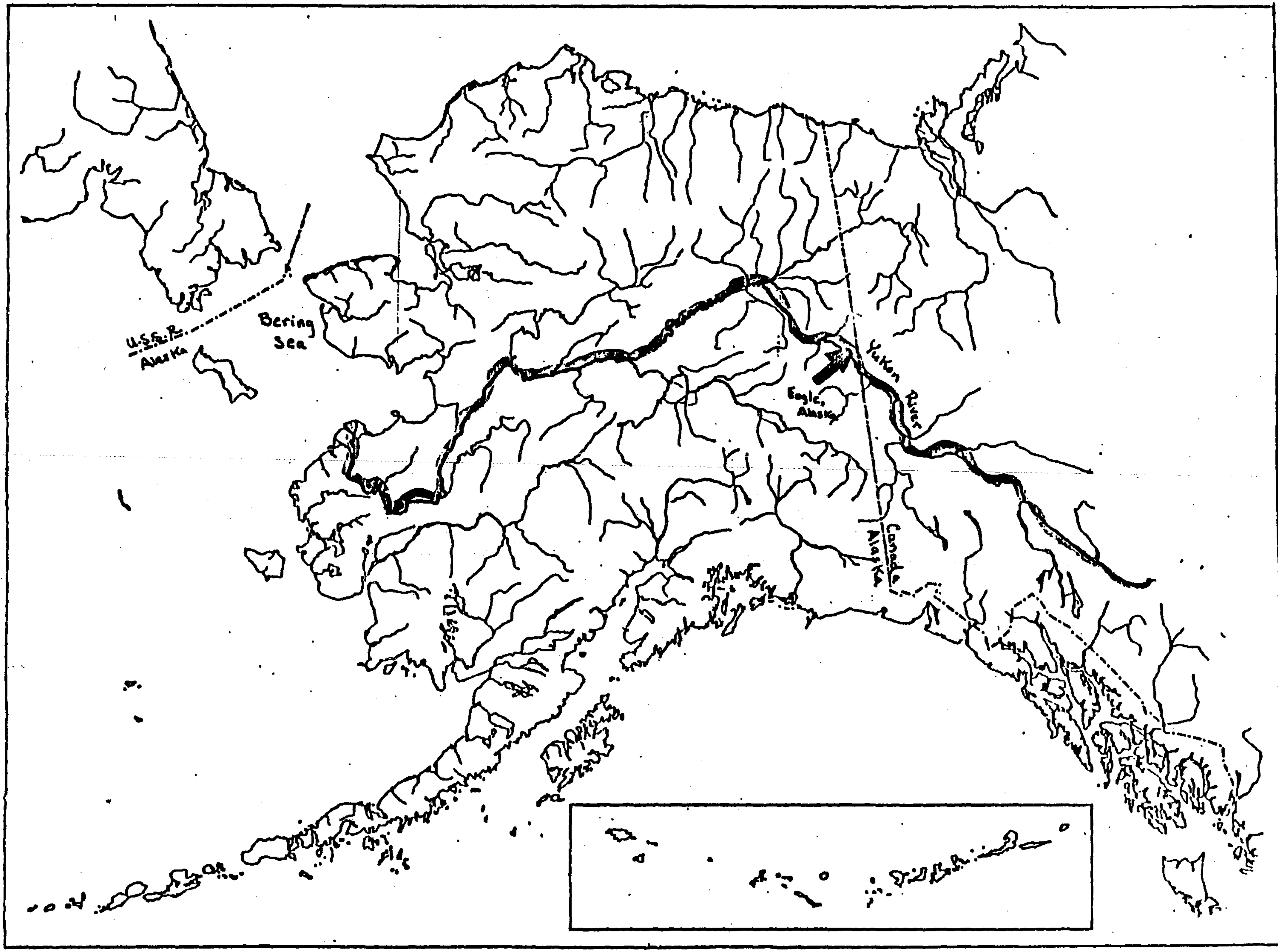
ASBESTOS INVESTIGATIONS in FISH and WILDLIFE in the UPPER YUKON RIVER REGION, ALASKA 1977 - 1982

(summary)

Robin L. West
Howard E. Metsker

U.S. Fish and Wildlife Service
Region 7
1011 E. Tudor Road
Anchorage, Alaska 99503

List of Tables and Figures


U.S.S.R.
Alaska
Bering Sea
Yukon River
Eagle, Alaska
Canada
Alaska

Asbestos Investigations in Fish and Wildlife
in the Upper Yukon River Region, Alaska.
1977-1982

Summary

High Concentrations of asbestos were first discovered in the upper Yukon River near Eagle, Alaska in the summer of 1977 by Fish and Wildlife Service Biologists. Fiber concentrations in excess of a billion fibers per liter were evident in the river cross-section analysis (See Table 1). Although no criteria exist for the protection of freshwater aquatic life, the Environmental Protection Agency (EPA) recognizes a zero concentration of asbestos for the maximum protection of human health, due to the carcinogenic properties of asbestos (EPA, 1980).

"Of the millions of current and former workers who have been heavily exposed to asbestos, one in ten will die from Cancer of the gastrointestinal tract" (Millette, et al., 1981).

The closest analogy as to how the carcinogenic action of asbestos occurs is in the "Oppenheimer effect" where the induction of sarcomas resulted from the implantation of apparently inert plastic membranes (Oppenheimer and Oppenheimer, 1955). Although it appears asbestos may be a significant cause of carcinomas, such cancers often appear after a latent period of 20 to 40 years (IARC, 1973) making cause and effect studies more difficult. Recently, researchers have suggested asbestos may have secondary carcinogenic effects by increasing hepatocellular carcinomas when in combination with hepatitis B virus (Meyers, 1981).

Owing to the implications to wildlife and human health further collections in the upper Yukon River Region were undertaken.

The initial water samples, and all subsequent water and fish samples were analyzed by Lake Superior Basin Studies Center, University of Minnesota at Duluth. Figure 1 depicts the procedures for analyzing water samples for asbestos. The sample is thoroughly mixed and filtered for organic material. It then is ashed, resuspended, filtered onto a nucleopore filter, carbon coated, and then random sections are prepared on an electron microscope (EM) grid. Fish tissue preparations differ slightly (see Figure 2). Organs are digested with 20 percent potassium hydroxide, whereas muscle is freeze-dried and then ashed before filtering and EM scanning.

Results of fiber analysis demonstrated that the asbestos was associated with natural soil minerals (rather than from mining). The fibers were relatively dull and rounded

FIGURE 1.

TRANSFER OF SAMPLES TO ELECTRON MICROSCOPE GRIDS FOR DETERMINATION OF FINE PARTICLE PRESENCE

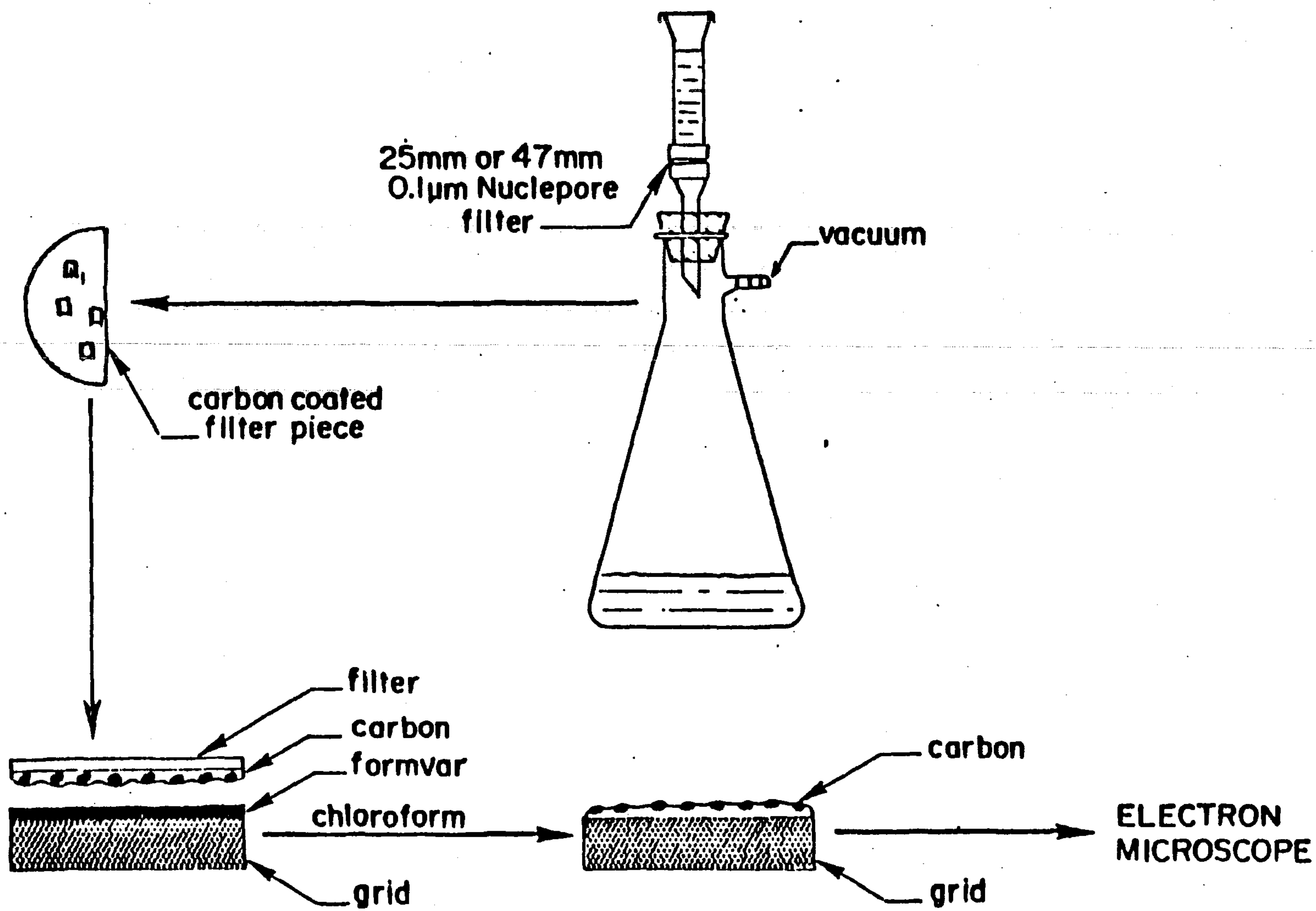
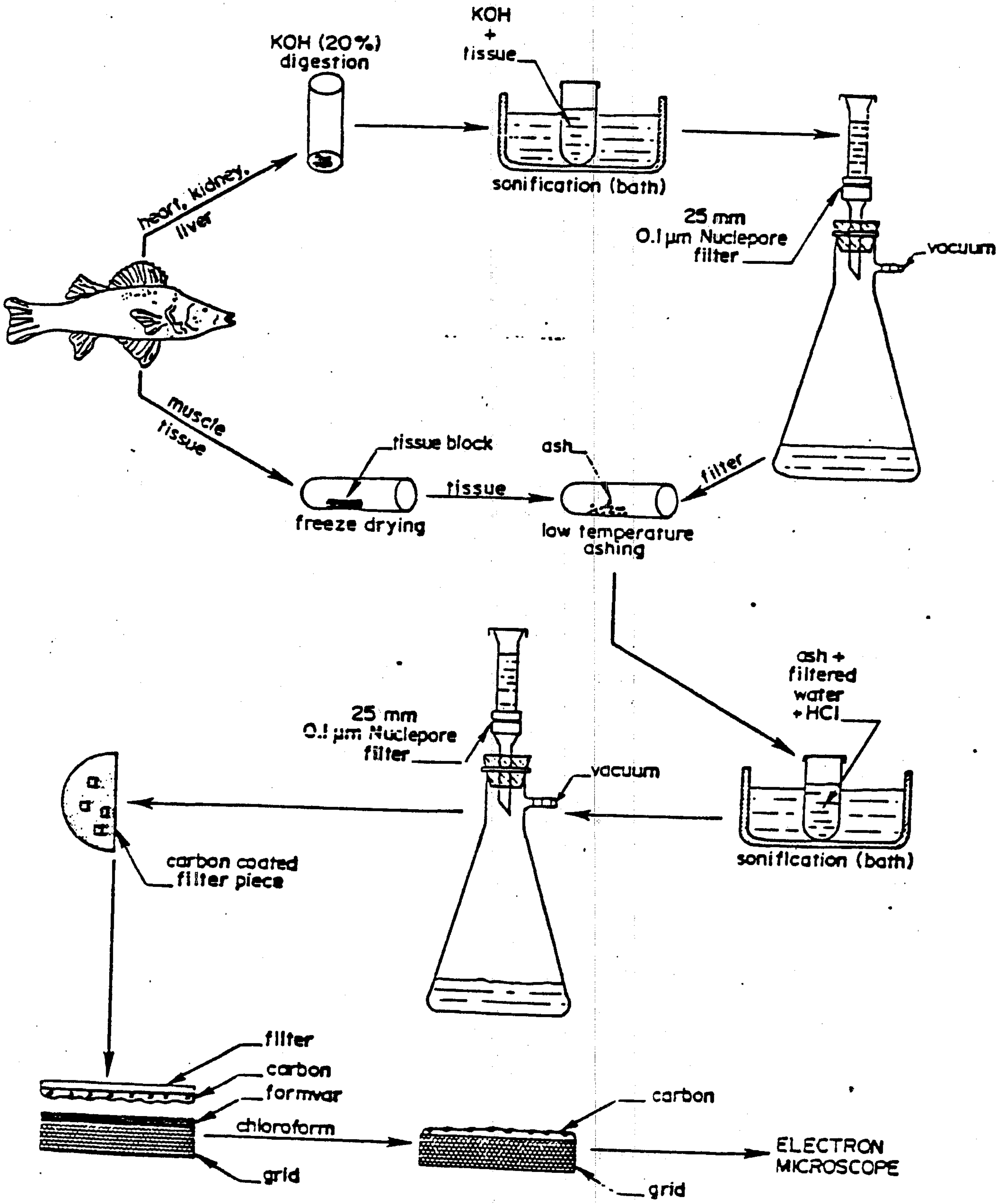


FIGURE 2.

TRANSFER OF FISH TISSUE SAMPLES TO ELECTRON MICROSCOPE GRIDS FOR DETERMINATION OF FINE PARTICLE PRESENCE.



rather than sharp and fibreous. They were also found to be chiefly hornblend, calcium-rich, and potassium-rich aluminum silicates with very little amosite or actinolite. Amphibole fibers were found at concentrations roughly 10 times higher than chrysotile fibers. Appropriate definitions are provided by Anderson and Long (1976).

fiber - any particle that has parallel sides and an aspect ratio greater than or equal to 3:1.

amphibole - a silicate mineral whose basic structure unit is a double silica chain, but with a variable composition and layered structure that is easily cleaved to form a fiber.

chrysotile - a nearly pure hydrated magnesium silicate, the fibrous form of the mineral serpentine, possessing a unique layered structure in which layers are wrapped in a helical cylindrical manner about the fiber axis.

Two fish were collected from the Yukon River near Eagle in July, 1979 and were analysed by the Lake Superior Basin Studies Center for fiber concentration. The results are presented in Table 2. These findings produced some of the first indications that asbestos could be taken in naturally by an animal and be passed through the gut wall to lodge in body tissues. The analyses were conducted on muscle tissue only and it was suspected (and later verified) that liver and kidney tissues would concentrate greater numbers of fibers. Overall the fish had roughly 100 times more asbestos fibers than fish analyzed from Lake Superior, an area of known asbestos contamination (David Marklund, personal communication, 1980).

Although amphibole fibers were found to be much more numerous in the river water than chrysotile fibers (see Table 1), the opposite was found to be true for concentrations within fish muscle tissue (based on the 2 samples taken in 1979). A possible explanation for this can be seen in Figures 3 and 4 where the average width of chrysotile fibers and of total fibers (all fibers including chrysotile) are depicted. It is probable that as chyrsotile fibers have a smaller width, they penetrate more easily.

Chrysotile fibers are believed to be more carcinogenic than amphibole fibers. Although no past research has demonstrated that chrysotile fibers may adversely affect fish, Pott, et al. (1974) showed that chrysotile, in which 99.8 percent of the fibers were shorter than 5 microns, produced intraperitoneal tumors in rats. Wagner, et al. (1973) reported that chrysotile, despite its initial long, curly character, tends to fragment into small particles in lung fluid. A single fiber may disintegrate into many extremely fine fibrils, and in this form it is highly carcinogenic.

Table 1.
Concentration (fibers/liter) of Asbestos in a Cross-section of the Yukon River near Eagle, Alaska, 1977

Sample	Amphibole	Non Amphibole	Chrysotile	Total
A	3.91×10^{9}	3.37×10^{9}	4.35×10^{8}	2.26×10^{10}
B	6.23×10^{9}	2.69×10^{9}	6.74×10^{8}	2.24×10^{10}
C	3.14×10^{9}	3.03×10^{9}	3.37×10^{8}	1.62×10^{10}
D	2.15×10^{9}	2.27×10^{9}	1.26×10^{8}	1.59×10^{10}
E	3.47×10^{9}	2.84×10^{9}	6.32×10^{8}	2.07×10^{10}

(Samples A,B,D, and E were taken 5 to 10 feet deep using a brass drop tube. Sample C was taken from 20 feet deep. Extreme current precluded sampling at greater depths. Sites were equally spaced with A near the Eagle side, C at mid-river, and E near the opposite bank.)

Table 2.
Asbestos Fiber Concentrations in Two Fish Taken near Eagle, Alaska, 1979

	Burbot (*Lota lota*)	Longnose Sucker (*Catastomus catastomus*)
Total Fibers per gram of muscle Tissue	132,000	81,000
*Estimate Total Fibers per Fish	6C,720,000	59,130,000
*Estimate of Total Fibers per Liter of Water in Fish	593,000 000	520,000,000

*Based on Levels in Muscle Tissue Only.

Figure 3. Graph of Average Total Fiber Width in Longnosed Sucker, 1979.

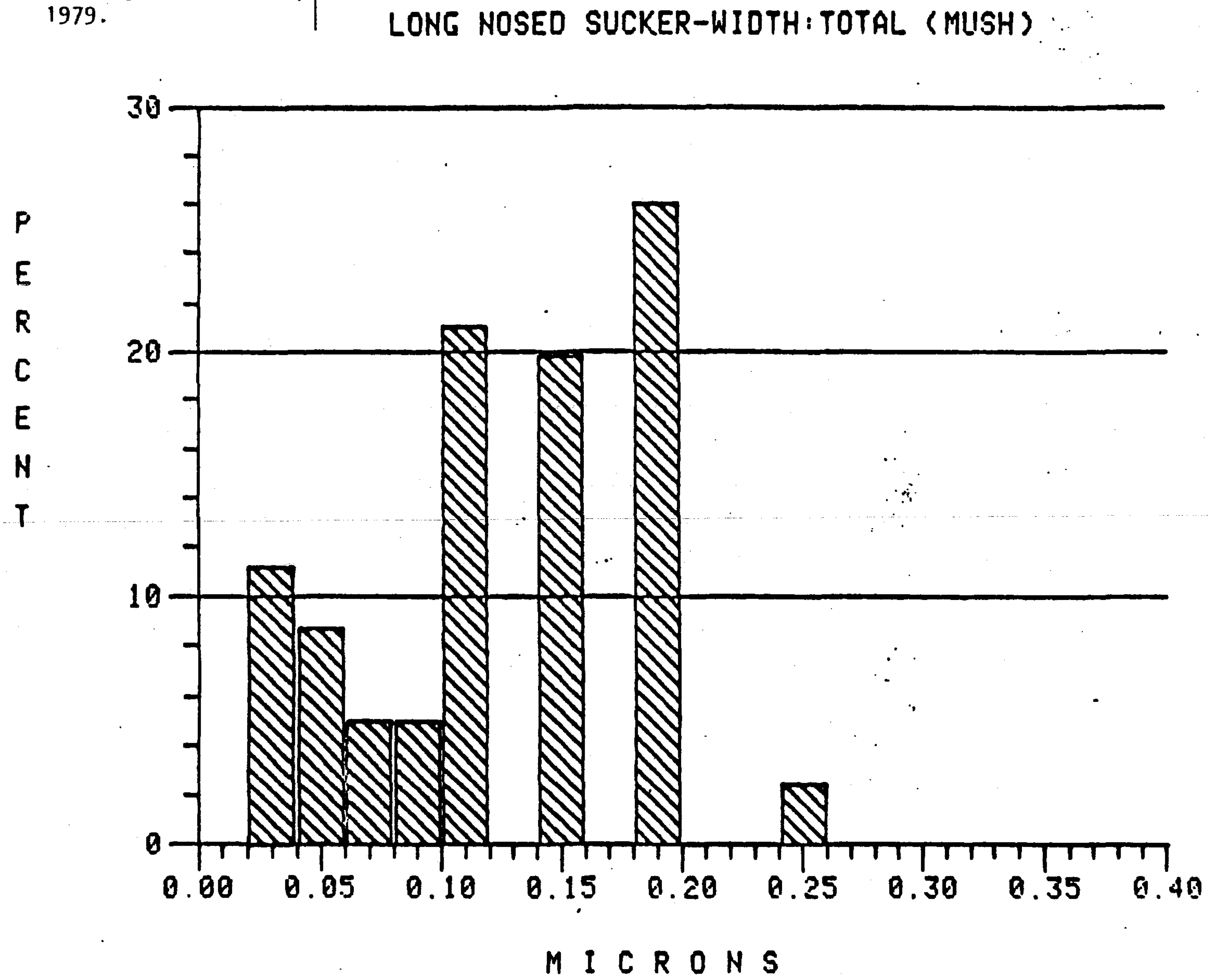
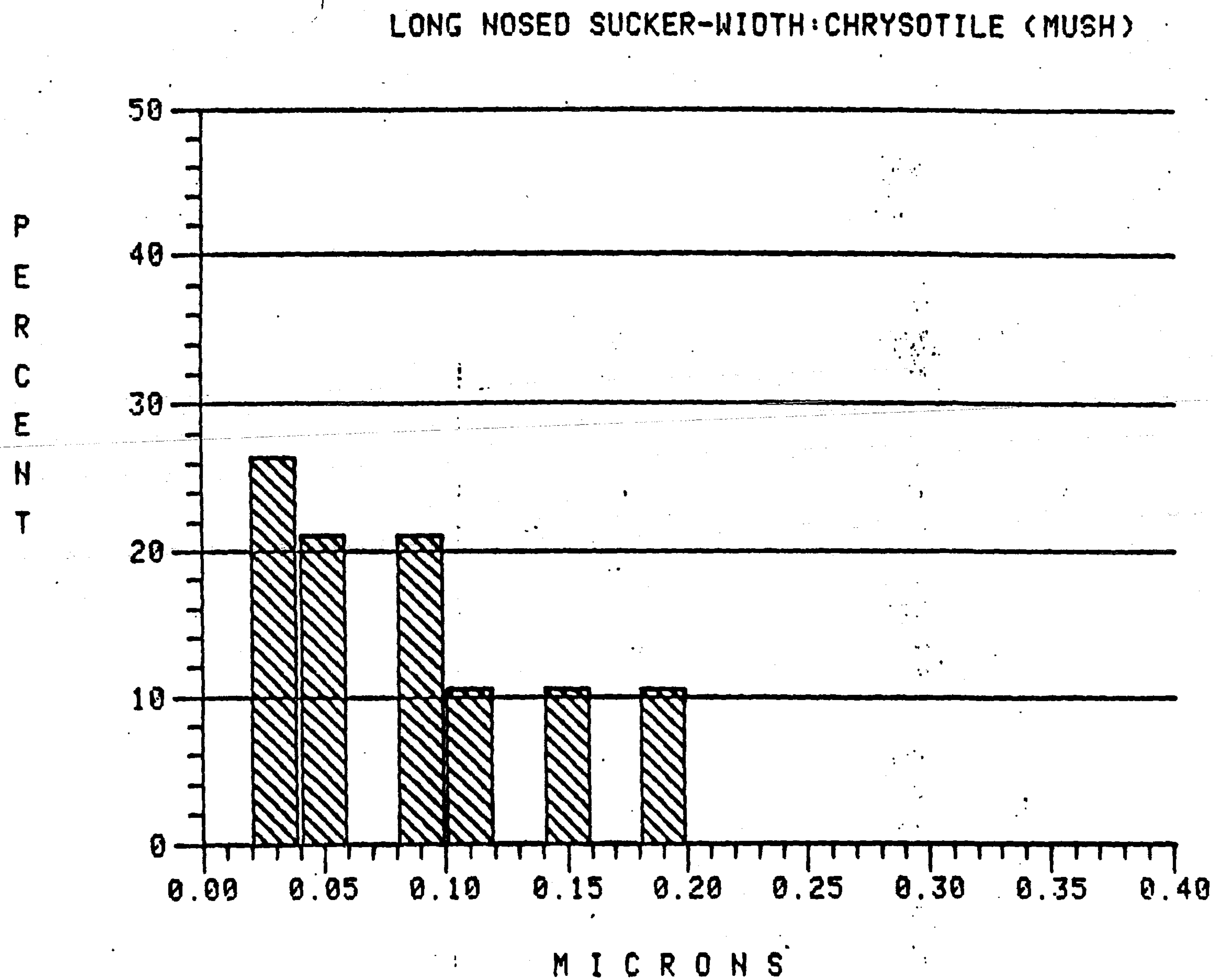


Figure 4. Graph of Average Chrysotile Fiber Width in Longnosed Sucker, 1979.



Even though the majority of asbestos in the Yukon River was believed to be of natural origin we decided to continue investigations because of the known human health hazards associated with asbestos, the lack of knowledge of the effects of asbestos on aquatic life, proposed major asbestos mine developments in the area, and the need to establish baseline data for any future monitoring. Summaries of asbestos analyses for samples collected in 1980 and 1981 are presented in tables 3 and 4 respectively. Fish species examined included: longnose sucker (Catastomus catastomus), burbot (Lota lota), king salmon (Oncorhynchus tshawytscha), Northern pike (Esox lucius), Sheefish (Stenodus leucichthys), Arctic grayling (Thymallus arcticus), and round whitefish (Prosopium cylindraceum). Sizes, ages, sampling, and handling techniques for all of the samples are available upon request.

A single black bear (Euarctos americanus) muscle, kidney, and liver tissue sample was also collected in 1981 (see Table 4). The bear, like many of the fish, was found to have concentrated asbestos fibers. The muscle tissue (taken from the head) had 230,000 chrysotile fibers per gram.

Analyses was also conducted in 1981 to determine if any major differences could be seen in fiber concentrations in muscle tissues in different locations in the fish (see bottom of Table 4). Results showed differences in fiber concentrations from anterior to posterior in the fish, with the gut region seemingly to concentrate the most, but due to the limited sample size no final conclusions were made.

In 1982 several water collections were made at various locations along the Yukon River and in two tributary streams (Table 5b). Although no samples were taken directly at Eagle, asbestos concentrations taken from near the Nation River (about 40 miles downstream) were much lower than those first discovered in 1977. The large difference is unexplained beyond obvious spatial and temporal variation including such possible factors as high rainfall preceding higher asbestos concentration values and dilution occurring below the Nation River and other clearwater tributaries. The highest asbestos concentration found in 1982 water samples occurred at Goose Island near St. Mary's in the lower Yukon River. A concentration of 354 million amphibole fibers per liter and over 75 million chrysotile fibers per liter was found at that location. These high values lead to many questions, such as: Do concentrations of asbestos separate out in the river channel or water column to make single grab samples an unreliable sampling method? Are there other sources of asbestos of significant amount that enter the Yukon River other than from the upriver deposits located in Canada and the Forty-mile area? Intensive sampling would be necessary to answer these questions.

Table 3.
Asbestos Research Summary, 1980

Water Samples		No. of Fibers per Liter	
		Amphibole	Chrysotile
Forty Mile River	South Fork	2.02 X 10^5	103 X 10^5
	North Fork	20.2 X 10^5	108 X 10^5
	@ O'Brien Ck.	20.2 X 10^5	46.5 X 10^5

Fiber Concentrations in Fibers/Gram of Tissue

Yukon River Fish	Amphibole	Chrysotile
Muscle King Salmon	<7.45* X 10^3	13.6 X 10^3
Liver King Salmon	8.4 X 10^3	50.8 X 10^3
Muscle Longnose Sucker	<13.5* X 10^3	312 X 10^3
Liver Longnose Sucker	10.8 X 10^3	32.3 X 10^3
Muscle Rearing King Salmon	< 19.4* X 10^3	10.1 X 10^3
Muscle Burbot	41.9 X 10^3	74.8 X 10^3
Liver Burbot	164.0 X 10^3	75.6 X 10^3
Muscle Round Whitefish	4.29 X 10^3	13.7 X 10^3
Liver Round Whitefish	123.0 X 10^3	119.0 X 10^3
Muscle Northern Pike	2.14 X 10^3	12.8 X 10^3
Liver Northern Pike	128.0 X 10^3	34.6 X 10^3
Muscle Sheefish	8.98 X 10^3	15.0 X 10^3
Liver Sheefish	54.3 X 10^3	23.8 X 10^3
Muscle Round Whitefish	1.12 X 10^3	6.75 X 10^3
Liver Round Whitefish	47.9 X 10^3	29.5 X 10^3
Muscle King Salmon	7.53 X 10^3	62.8 X 10^3
Liver King Salmon	26.7 X 10^3	95.2 X 10^3
Muscle Longnose Sucker	1.44 X 10^3	7.20 X 10^3
Muscle King Salmon	4.03 X 10^3	12.1 X 10^3
Liver King Salmon	37.2 X 10^3	101.0 X 10^3
Liver Arctic Grayling	280 X 10^3	153.0 X 10^3
Liver Arctic Grayling	362 X 10^3	116.0 X 10^3

Note Tissues were preserved in formalin in the field
(* Below detection limit)

Table 4
Asbestos Research Summary, 1981

alysis of 1 water; 1 sediment; 1 bear liver, muscle, and kidney; and 22 fish liver, kidney, and muscle tissues.
Collected near Eagle, Alaska

		King Salmon	Grayling	Pike	Sucker	Whitefish
scle	Amph.	--	<3.4* X 10^3	3.8 X 10^3	3.4 X 10^3	< 3.3* X 10^3
	Chry.	--	<3.4* X 10^3	284 X 10^3	10.2 X 10^3	3.3 X 10^3
ver	Amph.	11.6 X 10^3	<4.5* X 10^3	6.5 X 10^3	--	3.7 X 10^3
	Chry.	69.4 X 10^3	13.6 X 10^3	< 3.3* X 10^3	--	3.7 X 10^3
dney	Amph.	7.7 X 10^3	--	237.0 X 10^3	--	460.0 X 10^3
	Chry.	38.7 X 10^3	--	616.0 X 10^3	--	1020.0 X 10^3

		Fish from Yukon R. Sheefish	Burbot	Black Bear	Fish results (in fibers/gram of tissue) Water fibers/liter	Water and Sediment from Fortymile R. Sediment fibers/gram
scle	Amph.	--	< 3.5* X 10^3	13.3 X 10^3	2 X 10^6	1.4 X 10^6
	Chry.	--	7.0 X 10^3	230.0 X 10^3	Amphibole	Amphibole
ver	Amph.	3.5 X 10^3	3.2 X 10^3	< 3.9* X 10^3	&	&
	Chry.	17.8 X 10^3	181 X 10^3	15.7 X 10^3	10.6 X 10^6	19.8 X 10^6
dney	Amph.	50.5 X 10^3	< 4.1* X 10^3	3.2 X 10^3	Chrysotile	Chrysotile
	Chry.	490.0 X 10^3	36.7 X 10^3	41.0 X 10^3	fibers	fibers

scle Fiber Concentration Difference Anterior to Posterior

	ANTERIOR	MIDDLE (as in other samples above)	POSTERIOR
rthern Pike			
Amph.	4.4 X 10^3	3.8 X 10^3	< 3.5* X 10^3
Chry.	30.5 X 10^3	284.0 X 10^3	3.5 X 10^3
ngnose Sucker			
Amph.	<3.3* X 10^3	3.4 X 10^3	<3.5* X 10^3
Chry	9.9 X 10^3	10.2 X 10^3	3.5 X 10^3
rbot			
Amph.	8.2 X 10^3	< 3.5* X 10^3	4.9 X 10^3
Chry.	16.5 X 10^3	7.0 X 10^3	34.1 X 10^3

less than detection limit

Several fish and wildlife species also were collected in 1982 and examined at the Lake Superior Basin Study Center for asbestos concentrations (See Table 5a). Two fish, a sheefish and northern pike, were taken downriver near Mountain Village. Three wildlife species were taken in the upriver area between Eagle and Circle.

The beaver (*Castor canadensis*) was taken in the Yukon River near the Nation River, the raven (*Corvus corax*) from near Slaven cabin, and the spotted sandpiper (*Actitis macularia*) near the mouth of Woodchopper Creek. The single samples of each species cannot provide conclusions on species concentration factors or trends. They do however indicate, as have previous results, that various fish and wildlife species in and along the Yukon River concentrate asbestos fibers. The highest levels recorded in 1982 were 80,100 chrysotile fibers per gram of tissue in sheefish muscle and 71,400 chrysotile fibers per gram of tissue in spotted sandpiper kidney.

The spotted sandpiper, and other shorebirds and waterfowl, are major prey items for the endangered peregrine falcons that nest along the bluffs of the upper Yukon River. (Ritchie, 1979). Although no falcon samples have been analyzed, it is likely they too are concentrating asbestos fibers. Potential effects are unknown. Some investigators have postulated that asbestos may act as a synergist or catalyst to increase or initiate toxicity of a pollutant.

Since organochlorine pesticides have been linked to the decline of the peregrine falcon (Peakall, 1976) and have been found to be present in Yukon River falcons (Cade, et al., 1968) The question of interaction of asbestos fibers with pesticides in body tissues should possibly be addressed. The only completed research related to such a question found no increased toxicity of the pesticide endrin to fish in water with high asbestos concentrations (Carlson, et al., 1982). Further research is necessary to determine if problems can arise from asbestos in tissues with the presence of pesticides in avifauna.

A series of fish tissues were collected in 1981 from the upper Yukon and the Goodpaster River (acting as a control system) for histological examinations to determine potential asbestos-caused cellular changes. Twelve samples of seven species were collected from the Yukon River and nine samples of five species were collected from the Goodpaster River. The work was continued in 1982 but the Chena River was used as a control system, fewer numbers were taken, and the longnosed sucker was chosen as the primary species to be examined. The tissue samples were preserved in Bouin's solution in the field immediately after capture of the fish. Small sections of gill, liver, muscle, gut, kidney, and heart were taken from each sample. The samples were shipped, in the preservative, to the National Fishery Research Center, Seattle, Washington. Histopathological examinations were then performed by William T. Yasutake of the Research Center. Preparations and staining methodologies are described by Yasutake (1982 and 1983).

Table 5a.
Tissue Sample Fiber Concentrations in Several Species, 1982
(Results are in number of fibers per gram)

	Amphibole	Chrysotile
Beaver		
Muscle	8,500	21,400
Kidney	below detection	9,200
Liver	below detection	below detection
Sheefish		
Muscle	6,400	80,100
Northern Pike		
Muscle	below detection	7,500
Raven		
Muscle	2,700	below detection
Kidney	2,400	21,300
Liver	3,700	14,700
Spotted Sandpiper		
Muscle	8,500	14,100
Kidney	below detection	71,400
Liver	2,100	8,600

Table 5b.
Water Sample Fiber Concentrations in Single Grab Samples
from Various Locations
(Results are in fibers per liter)

	Amphibole	Chrysotile
Main Stem Yukon R. Approx. 5 Mi.above Circle	5,100,000	3,500,000
Charley R. near Mouth	900,00	1,300,000
Main Stem Yukon R. Approx. 1/2 Mi. below Nation R.	2,500,000	6,600,000
Fortymile R. @ O'Brien Cr. Bridge - Taylor Highway	200,000	1,700,000
Main Stem Yukon R. @ Goose Island near St. Mary's	354,000,000	75,800,000

Results of analyses of the 1981 samples showed a varied pattern of histopathological disorders from epithelial hyperplasia and hypertrophy in the Yukon samples to heavy parasite infestation of both sample groups.

These conditions, however, were often masked by post mortem changes. The additional samples analyzed in 1982 appeared to be more conclusive. Tables 6-9 provide summary information on these samples. These results helped substantiate conclusions from the 1981 work and demonstrated that significantly more severe tissue changes were occurring in fish from the Yukon River than from the control streams, especially gill and skin tissues. The results were not conclusive however, that asbestos was the cause of such changes. Abrasive action of almost any material probably could have caused the observed changes.

Many questions on the effects of asbestos to both aquatic and terrestrial organisms still need to be answered. Further investigations are needed to determine:

1) Threshold levels of asbestos which affect fish and other wildlife productivity, particularly the levels which may affect outmigrating salmon entering the Yukon from clearwater tributaries,

2) the extent of the threat of utilizing river water and local wildlife to the human residents of the region,

3) the major source(s) of the natural asbestos contamination,

4) methods of preventing further contamination from proposed large-scale mining operations in the area,

5) the rate of accumulation of asbestos in animals exposed to the contaminated water, and

6) the extent of significant contamination downriver.

Table 6. Samples collected for histopathological analysis.

Sample	Date	Species	Sex	Length	Weight	Location
LS-1-82	7/9/82	Longnose sucker	F	470 mm	760 g	Yukon R
LS-2-82	7/9/82	Longnose sucker	F	448 mm	800 g	Yukon R.
LS-3-82	7/9/82	Longnose sucker	F	462 mm	775 g	Yukon R.
LS-4-82	7/9/82	Longnose sucker	F	452 mm	820 g	Yukon R.
LS-5-82	7/9/82	Longnose sucker	F	470 mm	825 g	Yukon R.
NP-1-82	7/10/82	Northern Pike	M	597 mm	1810 g	Yukon R.
Controls:						
LS-con-1-82	9/16/83	Longnose sucker	F	456 mm	1025 g	Chena R.
LS-con-2-82	9/16/82	Longnose sucker	M	421 mm	895 g	Chena R.

From Yasutake (1982)

Table 7. Histopathology of fish from the asbestos-exposure study II.

ECE sample no.	NFRC case no.	Gill: Epithelial hypertrophy	Epithelial hyperplasia	Lamellar aneurysm	Epithelial Degeneration and/or necrosis	Epidermal sloughing	Few mucus cells	Possible *Sanguinicola* sp.	Other parasites
Longnose sucker									
LS-con-1-82	22-82-1	X	X	-	-	-	-	X	-
LS-con-2-82	22-82-2	X	-	-	-	-	-		-
LS-1-82	23-82-1	X	X	X	X	X	X	X	X
LS-2-82	23-82-2	X	X	X	X	X	X	X	-
LS-3-82	23-82-3	X	-	X	X	X	-	X	-
LS-4-82	23-82-4	X	-	X	X	X	X	X	-
LS-5-82	23-82-5	X	X	X	X	X	X	-	-
Northern Pike									
NS-1-82	24-82-1	X	-	-	-	-	-	X	X

From Yasutake (1982)

ble 8. Histopathology of fish from the asbestos-exposure study II.

		Kidney			Heart		Skin		Liver		Muscle	Gut
ECE mple no.	NFRC case no.	Intracytoplasmic "ceroid" in tubular epitheliu	Possible Sanguinicola sp.	Foreign bodies	Possible Sanguinicola sp.	Foreign Bodies	Epidermal degeneration and/or sloughing	Lack of mucus cells	Parasite	Vaculation	Tissue change	Tissue
ngnose sucker												
5-con-1-82	22-82-1	Few X	X	-	X	-	-	-	-	X	-	-
5-con-2-82	22-82-2	Few X	X	-	X	-	-	-	-	X	-	-
3-1-82	23-82-1	X	X	X	-	-	X	X	-	-	X	-
3-2-82	23-82-2	X	X	X	X	-	X	X	X	X	X	-
3-3-82	23-82-3	X	X	X	X	X	X	X	X1/	X	X	-
-4-82	23-82-4	X	-	X	X	-	X	X	X	-	X	-
-5-82	23-82-5	Few X	X	-	X	-	X	-	-	X	X	-
thern Pike												
-1-82	24-82-1	-	X	-	-	-	X2/	-	-	X	X	-

eracidia of Sanguinicola-like parasite.

ermal instead of epidermal involvment.

rom Yasutake (1982)

LITERATURE CITED

Anderson, C.H. and J.M. Long. 1976. Preliminary interim procedure for fibrous asbestos. Analytical Chemistry Branch, U.S. EPA Research Laboratory, Athens, GA 30601. 30 pp.

Cade T.J., C.M. White, and J.R. Haugh. 1968. Peregrines and pesticides in Alaska. The Condor 70(2): 170-178.

Carlson, A.R., et al. 1982. Cadmium and Endrin Toxicity to Fish in Waters Containing Mineral Fibers. U.S. Environmental Protection Agency, U.S. Gov. Printing Office - 559-017/0854.

Environmental Protection Agency. 1980. Ambient Water Quality Criteria for Asbestos. EPA Pub. no. 440/5-80-022, Washington, D.C. 145 pp.

IARC 1973. Monographs on the evaluation of carcinogenic risk of chemicals to man. Lyons, France. (International Agency for Research on Cancer) 2: 17-47.

Marklund, D.R. 1980. Supervisor, Environmental Services Laboratory, Lake Superior Basin Studies Center, University of Minnesota. (personal communication).

Meyers, H.A. 1981. Asbestos Levels in Rural Alaskan Drinking Water: Relationship to Primary Hepatocellular Carcinoma. A Research Proposal to the Alaska Council on Science and Technology. WAMI Med. Ed. Prog. U of A, Fairbanks.

Millette, J.R., R.L. Boone, M.T. Rosenthal and L.J. McCabe. 1981. The need to control asbestos fibers in potable water supply systems. The Science of the Total Environment (18) 91-102.

Oppenheimer, B.S., E.T. Oppemheimer, and I. Danishefsky, et. al. 1955. Further studies of polymers as carcinogenic agents in animals. Cancer Res. 15: 333-340.

Peakall, D.B. 1976. The Perigrine Falcon (Falco peregrinus) and pesticides. Canadian Field Naturalist 90(3): 301-307.

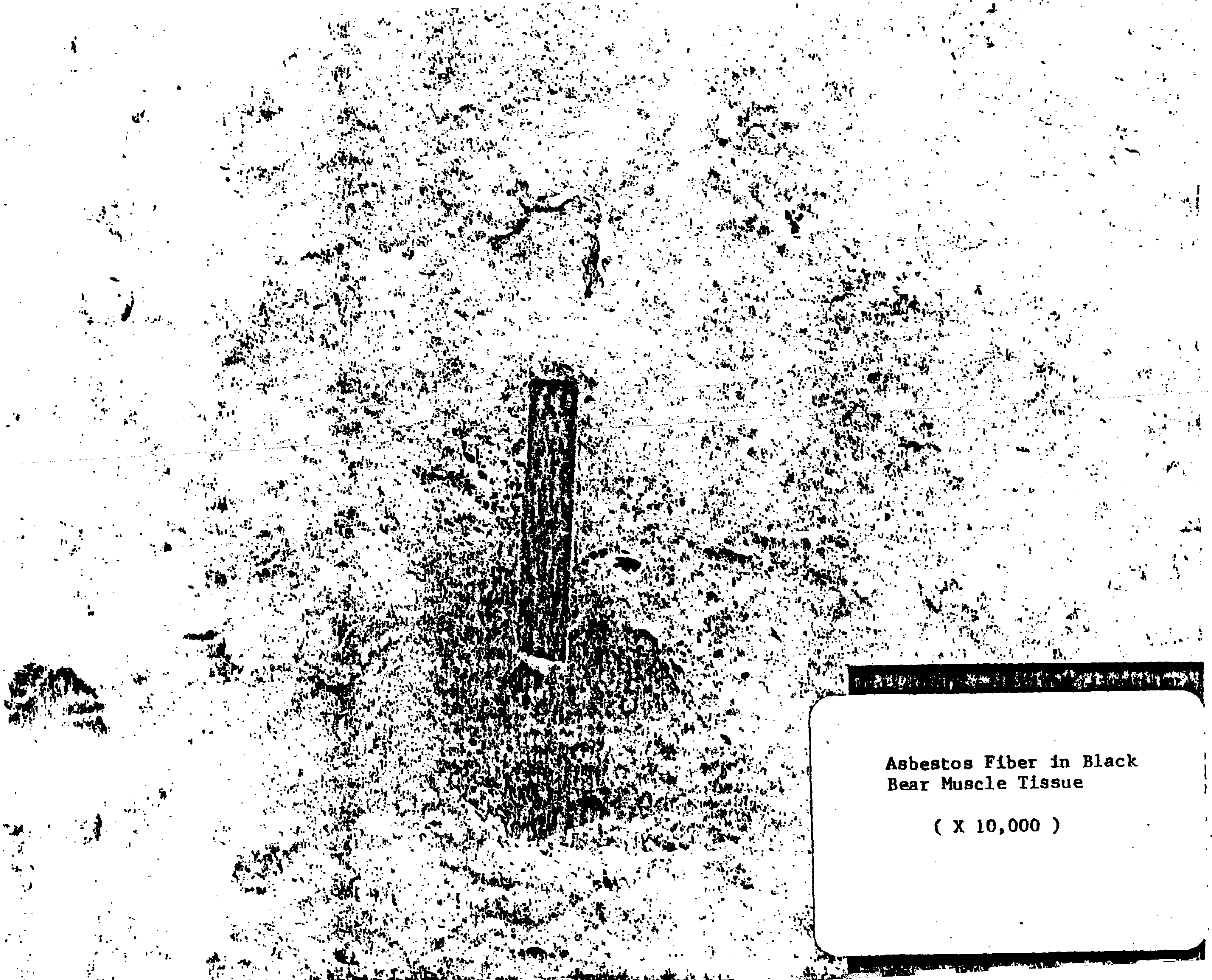
Pott, F., F. Huth, and K.H. Friedrichs, 1974. Tumorigenic effect of fibrous dusts in experimental animals. Environ. Health Perspect. 9: 313-315.

Ritchie, R.J. 1979. Prey of the Peregrine Falcon (Falco peregrinus anatum) on the upper Yukon river, Alaska, 1977-78. Alaska Bio. Res. Sp. Rep. to USFWS Reg. 7. Anchorage, AK. 23 pp.

Wagner, J.C., G. Berry, and V. Timbrell. 1973. Mesotheliomata in rats after inoculation with asbestos and other materials. Br. J. Cancer 28: 173-185.

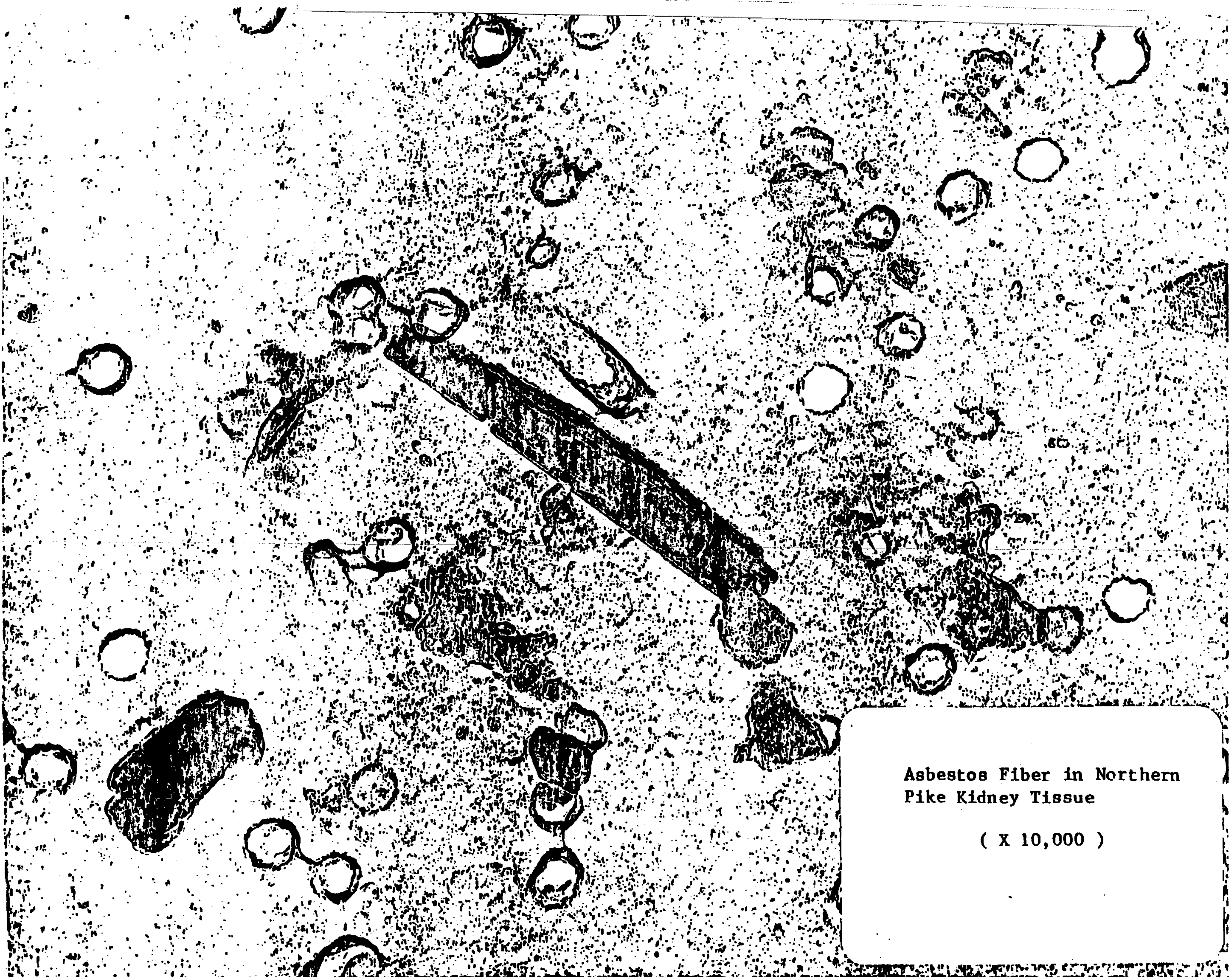
Yasutake, W.T. 1982. Histopathology of Asbestos-Exposed Fishes from the Yukon River, Alaska. Unpub. Rep. to USFWS-ECE, Anchorage, AK. 14 pp.

Yasutake, W,T, 1983. Histopathology of Asbestos-Exposed Fishes from the Yukon River, Alaska. II. Analysis of Additional Fishes. Unpub. Rep. to USFWS-ECE, Anchorage, AK. 16 pp.



Asbestos Fiber in Black Bear Muscle Tissue

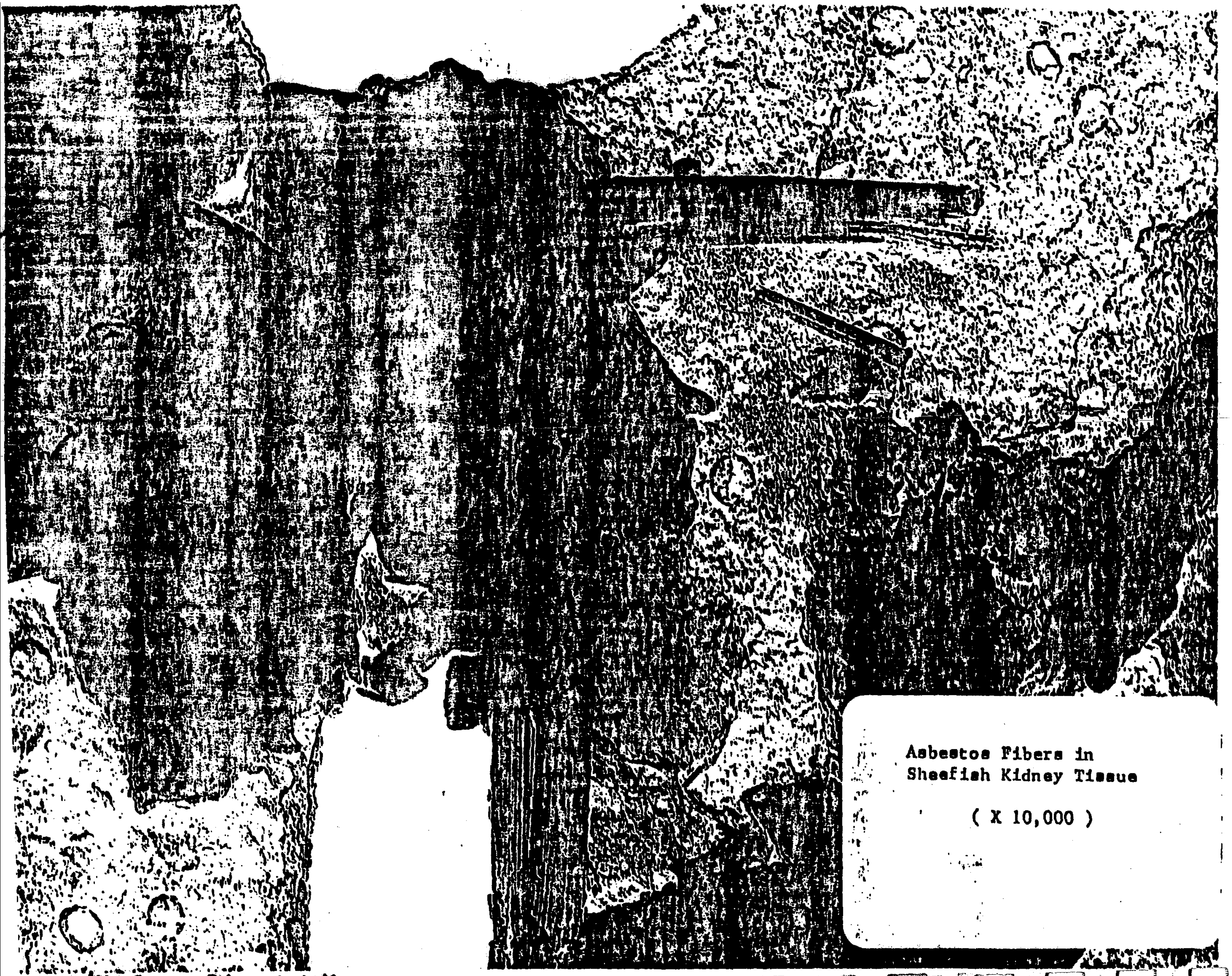
(X 10,000)



Asbestos Fiber in Northern Pike Kidney Tissue

(X 10,000)

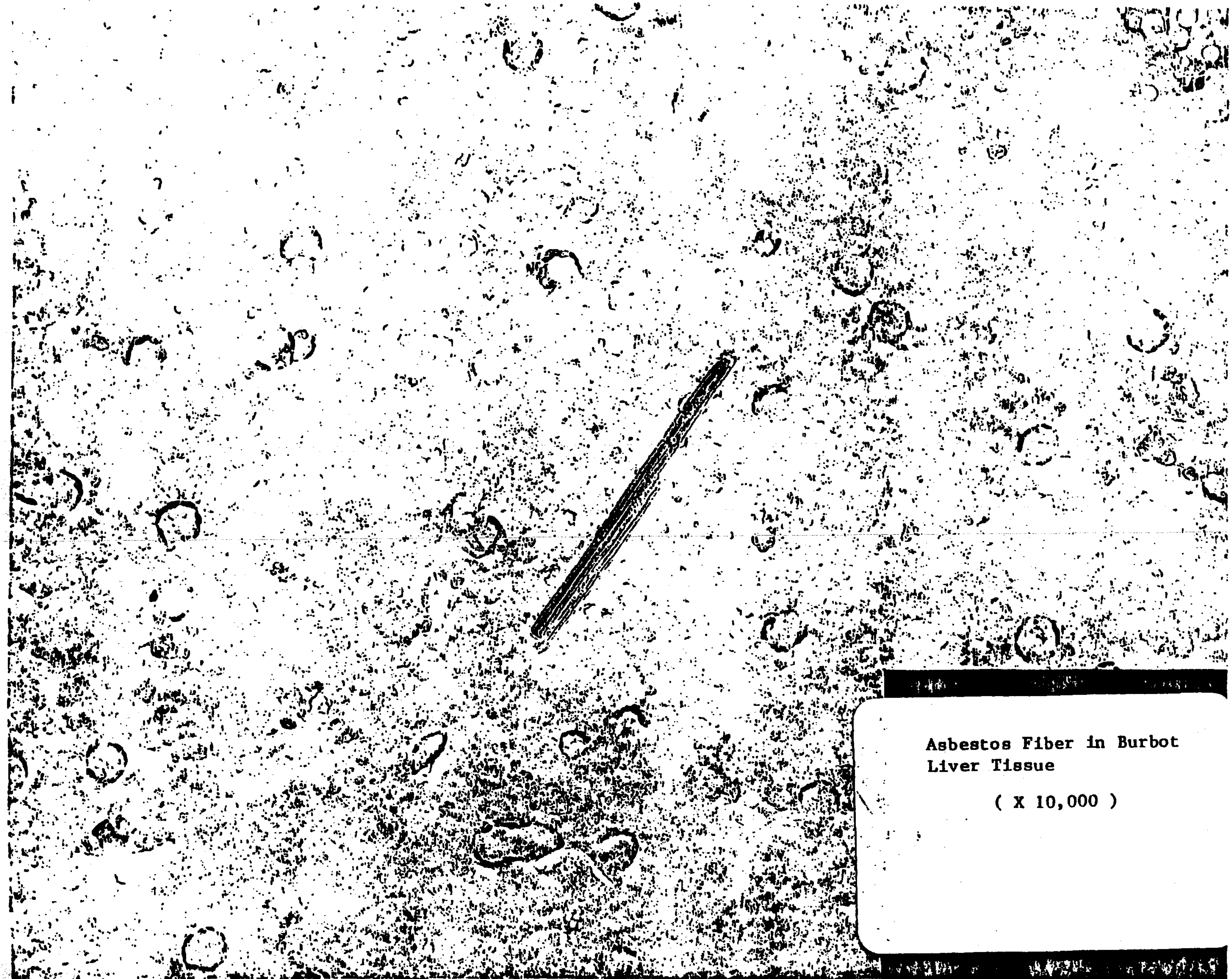
3429 NP. KIDNEY



Asbestos Fibers in
Sheefish Kidney Tissue

(X 10,000)

4103 SH. KIDNEY



Asbestos Fiber in Burbot Liver Tissue

(X 10,000)

3411-12 BB. LIVER