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Northern River Basins Study















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by
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Saskatchewan Research Council

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RADIONUCLIDE LEVELS IN FISH FROM LAKE ATHABASCA

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PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the Study Area by coordinating with existing programs and undertaking appropriate new technical studies.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

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NORTHERN RIVER BASINS STUDY
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Whereas the above publication is the result of word conducted under the Northern River Basins Study and the terms of reference for the work are deemed to be fulfilled,

IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
this publication be subjected to proper and responsible review and be considered for release to the public.

F.J. Wrona — 30 Nov 93
(Dr. F.J. Wrona, Ph.D., Science Director) (Date)

Whereas it is an explicit term of reference of the Science Advisory Committee "to review, for scientific content, material for publication by the Board",

IT IS HERE ADVISED BY THE SCIENCE ADVISORY COMMITTEE THAT;
this publication has been reviewed for scientific content and that the scientific practices represented in the report are acceptable given the specific purposes of the project and subject to the field conditions encountered.

SUPPLEMENTAL COMMENTARY HAS BEEN ADDED TO THIS PUBLICATION: [ ] Yes [ ] No

P.A. Larkin — Dec 14/93
(Dr. P. A. Larkin, Ph.D., Chair) (Date)

Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,

IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public.

Bev Burns — Dec. 16, 1993
(Bev Burns, Co-chair) (Date)

Lucille Partington — Dec. 16, 1993
(Lucille Partington, Co-Chair) (Date)

RADIONUCLIDE LEVELS IN FISH FROM LAKE ATHABASCA

STUDY PERSPECTIVE

Extensive uranium mine-mill operations were in place around Lake Athabasca during the 1950s to the early 1980s and some mining continues today. Residents of the area have concerns that tailings from these mines may enter Lake Athabasca causing radioisotope contamination of fish.

In February 1993, the Northern River Basins Study contracted The Delta Environmental Management Group Ltd. to supervise the collection of fish by local native technicians from traditional winter harvest areas on the western end of Lake Athabasca and from the Peace-Athabasca Delta. These collections were made to determine the levels of radionuclides and chemical contaminants (associated with upstream developments) in fish from traditional winter harvest areas.

Not all the fish collected were submitted for radionuclide analysis. A hierarchial approach was used whereby those fish thought most likely to have been exposed were tested. Because of past mine-mill operations in the Uranium City area on the north side of Lake Athabasca, fish from the two Lake Athabasca sites, Hook Point and Bustard Island, were submitted for analysis. The results of the analyses revealed that radionuclide levels in bone and muscle tissue were either slightly above or at or below detection limits. These results are consistent with radionuclide levels reported for fish from other lakes in northern Saskatchewan that are not exposed to uranium mine-mill operations. Further testing of fish for radionuclide contamination in the Peace-Athabasca Delta is deemed unnecessary within the context of the Northern River Basins Study.

Related Study Questions

3) *Who are the stakeholders and what are the consumptive uses of the water resources in the river basins?*

4a) *Describe the contents and nature of the contaminants entering the system and describe their distribution and toxicity in the aquatic ecosystems with particular reference to water, sediment and biota.*

6) *What is the distribution and movement of fish species in the watersheds of the Peace, Athabasca and Slave rivers? Where and when are they most likely to be exposed to changes in water quality and where are their important habitats?*

8) *Recognizing that people drink water and eat fish from these river systems, what is the current concentration of contaminants in water and edible fish tissue and how are these levels changing through time and by location?*

12) *What native traditional knowledge exists to enhance the physical science studies in all areas of enquiry?*

REPORT SUMMARY

In February 1993, the Northern River Basins Study contracted the collection of fish from two traditional winter harvest sites, Hook Point and Bustard Island, at the west end of Lake Athabasca. This collection was made to address the concerns of local residents about possible contamination of fish, used for human consumption, by upstream industrial and municipal developments and uranium mine-mill operations around Lake Athabasca.

A total of twenty pike, twenty lake whitefish, eleven white suckers and one longnose sucker from the collection were submitted to the Saskatchewan Research Council for radiochemical analysis and gross pathology examination. Muscle tissue (flesh) and bones from each of the fish were prepared for radiochemical analysis. Most of the results for lead-210, polonium-210, radium-226 and thorium isotopes were near or below the detection limit. Uranium was the only radioisotope that exhibited mean concentrations slightly above the detection limits (0.000013 Bq/g flesh, 0.0002 Bq/g bone). The mean values were 0.000015 Bq/g flesh and 0.00023 Bq/g bone for pike; 0.000015 Bq/g flesh and 0.00023 Bq/g bone for sucker; and 0.000026 Bq/g flesh and 0.00057 Bq/g bone for whitefish. Only the whitefish values were significantly above detection limits.

The radioisotope levels found in these fish from the west end of Lake Athabasca are equivalent to the lowest found in fish from lakes in northern Saskatchewan that have not been exposed to uranium mine-mill operations. Eating these fish would not change the normal dietary intake of radionuclides. Drinking one litre of water containing uranium at levels similar to the Guideline for Canadian Drinking Water Quality would provide a daily dietary intake of these radioisotopes equivalent to eating 47 kilograms of fish from the west end of Lake Athabasca.

The gross pathology examination revealed that the samples were typical of fish from other water bodies in the Athabasca Basin.

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INTRODUCTION

This study was undertaken as a contract with the Northern River Basin Study, Edmonton, Alberta to perform radiochemical analysis and biological examinations of fish samples from Lake Athabasca. There was concern that the uranium mine-mill operations that took place near the north shore of the lake during the 1950s to the early 1980s may have produced contamination that would affect fish in the lake. One of the first studies of radioisotope contamination in fish concentrated on the area immediately adjacent to the Eldorado Nuclear mine-mill operation (Swanson). The lakes and creeks effected by that milling operation do not drain directly into Lake Athabasca but flow through a series of other water bodies before reaching it. Another study was conducted at Langley Bay which has been contaminated with tailings from the Gunnar Mine (Waite et al). Due to the limited number of radionuclide measurements on Lake Athabasca fish, this study was undertaken to determine if there has been sufficient radionuclide contamination reaching the lake to affect the levels in fish.

Tailings from the Eldorado mill were deposited in a small lake which drained into a creek that continued through 3 other small lakes and finally into Beaverlodge Lake (Ruggles and Rowley). Barium chloride was added to the outflow of the second small lake in order to precipitate barium sulfate which coprecipitates radium sulfate. Most of the precipitate settled out in the 3rd and 4th small lakes. This removed a large fraction of the dissolved radium from the flow into Beaverlodge but had very little effect on dissolved uranium. Measurements made in 1981 (Swanson) showed that uranium levels in Beaverlodge lake near the point of the Tailings Creek outflow varied from 150 to 900 μg/L depending on the season of the year and the sampling location. Radium-226 and lead-210 concentrations in the lake were below drinking water standards. Consequently, the only radionuclide that might be transported into Lake Athabasca (Black Bay), in measurable levels, would be uranium.

Tailings from the Gunnar Mine which operated from 1955 to 1964 were initially deposited into Mudford Lake. Some of the tailings were subsequently washed from the lake, through a drainage channel, into Langley Bay. These untreated tailings contain significant amounts of radium-226 and lead-210 which have contaminated the water in the bay. Langley Bay is connected to Lake Athabasca by a narrow, shallow channel.

The Northern River Basin Study group arranged to have fish collected in February, 1993 from Lake Athabasca near Bustard Island and Hook Point (Figure 1). A large number of these fish (northern pike, suckers and lake whitefish) were submitted to the Saskatchewan Research Council Analytical Laboratory for radiochemical analysis. Not knowing what levels might exist in the fish, it was decided to do a complete analysis for all of the major, naturally occurring radioisotopes. In addition, the fish were to be examined by a biologist to check for any abnormal growth problems or diseases. The specimens were received at the SRC Laboratory in March, 1993 and the required examinations, measurements and radiochemical analyses were performed during the following two months. Tables 6 and 7 contain data on the age, sex, length and weight of the fish analyzed in this study. The collection of the fish is described in the report by Balagus et al.

ANALYSIS PROCEDURES

The fish specimens were received and stored frozen until examined and prepared for analysis. Groups of 10 to 20 fish were allowed to thaw overnight and then were examined by the biologist during the process of gutting and skinning. The head and a suitable portion of the body were weighed and sealed in a plastic cooking bag. This was boiled in a large beaker of water until cooked. Cooking aids in the complete separation of bone from the flesh which was done by hand sorting. Any liquid that separates from the fish is recombined with the flesh during this process. The weights of the separated bone and flesh were recorded. Subsamples of both the bone (5 g) and flesh (20 g) were taken for the lead-210 and polonium-210 analysis. This cooked tissue was digested with nitric - perchloric acids to produce a clear aqueous solution. Polonium is volatile at relatively low temperatures and would be lost in the normal ashing procedure used to prepare samples for uranium, radium and thorium analysis. Although lead is less volatile than polonium some can be lost if reducing conditions occur during the final high temperature stage of ashing. For this reason, lead is normally included with polonium in the acid digestion procedure. Known amounts of polonium-208 and inactive bismuth are added at the beginning of the acid digestion to serve as recovery monitors. The digestion is performed by repeatedly heating the sample with nitric acid until most of the organic matter has decomposed. Next, additional nitric acid and 5-10 mL of perchloric acid are added and the sample is gently heated until a colorless solution is obtained along with fumes of perchloric acid. Most of the perchloric acid is removed by continued heating. After cooling, the sample is diluted with hydrochloric acid and water to produce a 0.5 M

hydrochloric acid solution. The sample is first taken through the polonium-210 procedure and then through the lead-210 procedure.

Ashing of bone and flesh is started by first charring the samples in open pans on a hot plate. Most of the organic material is volatilized while some is reduced to a black char. The sample is then transferred to a temperature programmable furnace where the temperature is gradually increased to 550 °C. If the ash is not white at this stage the sample is treated with a solution of ammonium nitrate and reheated until all black carbon is eliminated. Separate portions of the ash are dissolved in nitric acid for each of the uranium, radium and thorium procedures.

POLONIUM-210 PROCEDURE

The prepared 0.5 M hydrochloric acid sample solution is transferred to a plastic container which has a polished silver disk mounted in its bottom so that only one side of the disk is exposed to the liquid. The contents are stirred for several hours during which time the polonium plates onto the silver surface. The alpha spectrum of the disk is measured in a vacuum chamber, alpha spectrometer. The polonium-208 peak is used to calculate the recovery which is used to correct the polonium-210 counts. A calibration curve prepared from plated aqueous standards is used to calculate the amount of polonium-210 contained in the sample. The relative standard deviation for this procedure varies from ±4% to ±10% for polonium concentrations greater than 0.1 Becquerels (Bq). The detection limit is 0.005 Bq.

LEAD-210 PROCEDURE

The solution remaining after the polonium deposition is adjusted to 2 M hydrochloric acid. It is transferred to a separatory funnel and extracted twice with a solution of 0.1% diethylammonium diethyldithiocarbamate in chloroform. The chloroform extracts are evaporated to dryness and then dissolved in nitric acid. This aqueous phase contains the added bismuth carrier and bismuth-210 which is the daughter of lead-210. The beta emissions of lead-210 are too weak to be measured efficiently by window type counting systems whereas the betas of bismuth-210 are easily detected. The short half-life of bismuth-210 (5.0 days) means that it will normally be in equilibrium with its lead-210

parent and have an identical activity. A small aliquot of the aqueous extract is diluted and analyzed for bismuth by atomic absorption spectrometry. The concentration of bismuth is used to calculate the recovery through the procedure and correct the final lead-210 value. The remainder of the nitric acid digest is diluted with water and the pH adjusted to 8. This causes bismuth oxychloride to precipitate. The precipitate is separated, redissolved in HCl and then diluted to reprecipitate bismuth oxychloride. The precipitate is collected on a membrane filter, covered with aluminum foil and counted in a low background, beta counter. Aqueous standards containing bismuth-210 are prepared in the same manner and used to calibrate the counting system. The detection limit of this procedure depends on the background of the counting system. For a background of 0.3 counts per minute (cpm) the detection limit is approximately 0.02 Bq and at 0.75 cpm it is 0.037 Bq. The relative standard deviation for this method is approximately ±6% for activities 50 times the detection limit.

RADIUM-226 PROCEDURE

A weighed amount (approximately 1 gram) of flesh or bone ash is dissolved in nitric acid. The solution is diluted to several hundred millilitres, lead chloride is added and then the lead is precipitated by adding potassium sulfate and sulfuric acid. The lead sulfate precipitate contains the radium from the sample. The precipitate is isolated and dissolved in alkaline ethylenediaminetetraacetic acid (EDTA). A few milligrams of barium chloride are added to this solution and then the pH is adjusted to 4.5 which causes barium-radium sulfate to precipitate. The precipitate is redissolved in EDTA and reprecipitated. This precipitate is filtered on a membrane filter, covered with a zinc sulfide coated mylar disk and counted on a bare photomultiplier counter after a suitable ingrowth period. The relative standard deviation for this procedure varies from ±4% to ±10% depending on the concentration and the nature of the original sample. The detection limit is 0.005 Bq.

THORIUM ISOTOPES PROCEDURE

Flesh or bone ash (~1 g) is dissolved in nitric acid after adding thorium-234 as a tracer. The solution is diluted with water to about 500 mL, potassium sulfate is added and barium chloride is added to precipitate barium-thorium sulfate. The precipitate is separated and redissolved by heating with concentrated sulfuric acid. The dissolved precipitate is reprecipitated in a potassium sulfate - hydrochloric acid solution. This precipitate is separated and dissolved in alkaline EDTA. A small amount of cerium is added to the solution and precipitated as the hydroxide. This small mass of precipitate carries the thorium and can be filtered onto a membrane filter for counting. Recovery of the added thorium-234 tracer is measured by beta counting the prepared membrane filter. The alpha spectrum of the individual thorium isotopes (Th-228, Th-230 and Th-232) is measured with a vacuum chamber, alpha spectrometer. The alpha spectrometer is calibrated by preparing standards from an aged thorium salt in which the Th-228 is known to be in equilibrium with Th-232. The detection limit is approximately 0.01 Bq. The relative standard deviation is ±5% to ±10% for concentrations above 0.2 Bq.

URANIUM PROCEDURE

Uranium is determined directly on the flesh or bone ash by Delayed Neutron Counting. The sample (1-2 grams) is weighed into a polyethylene capsule and sealed. The capsule and contents are irradiated in a nuclear reactor for 1 minute, pneumatically transferred to a neutron detector and the total number of neutron disintegrations over a 1 minute period are measured. The neutron count rate is a measure of the uranium-235 content of the sample. Uranium-235 and uranium-238 normally occur in a fixed ratio which corresponds to 0.72% uranium-235. Consequently, a measure of the uranium-235 content can be used to calculate the uranium-238 content. This method has a detection limit of approximately 0.1 micrograms of uranium-238. The relative standard deviation for homogeneous materials is ±2% for levels of uranium-238 exceeding 50 μg. For solid samples that are not ground extremely fine or well mixed this often increases to ±5%.

ANALYTICAL RESULTS

The analytical results for the determination of the various radionuclides on 52 fish samples are listed in Tables 1 to 3. Samples with the prefix PO were collected from the Hook Point site on Lake Athabasca. Those with the prefix SH are from the Bustard Island site. The suffix WH corresponds to whitefish, SU to sucker and PI to northern pike.

The gross pathology data sheets prepared by Barry Paquin have not been compiled into tabular format but are left in Barry's original handwriting. To quote from Barry's letter, "I observed nothing in the samples which I have not typically seen in other specimens from water bodies in the Athabasca Sandstone Basin". In his letter he goes on to list a few of his more common observations. Barry has been collecting and examining fish from northern Saskatchewan lakes for over 18 years.

The radiochemical results reported in Tables 1 to 3 show most of the results near or below the detection limits for lead-210, polonium-210, radium-226 and thorium isotopes. The results for uranium are below or slightly above the detection limit. Uranium-238 has a low specific activity and is more sensitively determined by mass analytical techniques than by radioactivity measurements. For example, the most sensitive radiochemical technique, alpha spectroscopy, has a detection limit of 0.01 Bq (1 μg). The mass detection techniques, delayed neutron counting and plasma - mass spectrometry have detection limits of 0.1 μg and 0.05 μg respectively. All uranium determinations were performed by delayed neutron counting on flesh ash or bone ash.

The ash content of fish flesh averages about 1.06% for northern pike and 1.27% for both whitefish and sucker. For bone, the average ash content for northern pike is 16.8% and the other two species average about 14%. A detection limit of 0.1 μg/g on the ash would correspond to a detection limit of 0.001 μg/g for wet flesh and 0.015 μg/g for wet bone. Wet tissue weights are based on the cooked material. Uranium-238 mass can be converted to activity by multiplying μg by 0.0123 to obtain Becquerels. The corresponding detection limits expressed in activity would be 0.000012 Bq/g wet flesh and 0.0002 Bq/g wet bone. The detection limits for uranium are lower than for any of the other radionuclides. All uranium results reported in the Tables have been converted from μg/g to Bq/g.

Detection limits for radium-226 are 0.00005 Bq/g for flesh and 0.0008 Bq/g for bone. For thorium isotopes these are 0.0001 Bq/g and 0.0015 Bq/g respectively. The tabulated data shows variable detection limits for polonium-210 and lead-210. This is due to the variable sample size that was taken for analysis. In some cases the digested sample solution was split between lead and polonium to save on digestion costs. In other cases, separate digestions were performed for each radionuclide. This variation resulted from the uncertainty at the beginning of the project as to whether polonium determinations would be performed on all samples.

As previously stated, most of the results except those for uranium are below or very close to the detection limit. The detection limits that are used here are the 1 σ standard deviations. This means that it is possible to get results 2 to 3 times the detection limit that may be false positives. Another uncertainty arises from the possibility of contamination at these extremely low activities. All of the radionuclides being measured are heavy metals that have a great tendency to adsorb on the surface of glassware used in the preparation of the samples. Although stringent procedures are used to clean glassware between uses, it is still possible for trace contamination to carry over from standards to the low level samples.

QUALITY CONTROL DATA

The radionuclide standards for Ra-226, Pb-210 and Po-210 used in this study were certified calibration standards from Amersham Laboratories. Thorium calibration standards were prepared from aged thorium nitrate, also obtained from Amersham Laboratories. Since each sample was completely dissolved, the original matrix (flesh or ash) has minimal effect on the results obtained. This has been confirmed by previous lab studies of spiked samples. Calibrations for uranium analysis by delayed neutron counting were prepared using certified rock and ore standards from CANMET, Ottawa. There is virtually no matrix effect for solid samples analyzed by delayed neutron counting. The QC data for this project consisted of analyzing laboratory control standards (prepared from the certified standards) and fish samples in duplicate. The data for duplicate determinations are presented in Table 4. Additional data for control standards and duplicates slightly above the detection limits are presented in Table 5. This data is a summary of the results obtained on hundreds of standards and samples analyzed over a 7 year period.

The duplicate analyses for radium-226 and thorium isotopes which are primarily at the detection limit do not show any signs of random variation which might occur if contamination was a problem. Since all the values are at the detection limit it is not possible to perform a statistical analysis of the data. Many of the uranium results are above the detection limit. The overall standard deviation which was calculated from the absolute difference between each pair divided by $\sqrt{2}$ gave a value of ±0.00011 Bq/g. At the detection limit (0.00018 Bq/g on bone ash) the relative standard deviation would be ±60% as compared to the expected ±100%. At 10 times the detection limit (0.0018 Bq/g) the relative standard deviation decreases to ±6% which is much less than the expected ±20%. Consequently, all of the uranium duplicate determinations are well within acceptable control limits.

The lead-210 determinations were performed in 9 batches of 4 to 15 samples. A laboratory control standard was analyzed with each batch. This standard was made up from the Amersham certified standard to contain 3.42 Bq. The individual results were as follows: 3.40, 3.65, 3.17, 3.31, 3.09, 3.58, 3.49, 3.49, 3.56. These result in a mean value of 3.42 Bq with a relative standard deviation of ±5.6%. This is in good agreement with the expected rsd of ±6%.

Polonium-210 determinations were performed in 10 batches ranging in size from 6 to 15 samples. The control standard was made up from the same Amersham certified solution as was used for lead-210 and also contained 3.42 Bq. The results were as follows: 3.64, 3.50, 3.60, 3.78, 3.38, 3.70, 3.20, 3.70, 3.57, 3.44. The mean is 3.55 Bq with an rsd of ±4.9%. Although biased high by approximately 3.5% the relative standard deviation is at the low end of the expected range. These results are well within acceptable control limits.

One batch of thorium isotope determinations was performed which contained all of the samples analyzed. A control sample containing 0.204 Bq of Amersham aged thorium nitrate was analyzed with this batch. The value for the control standard for this batch, the previous batch and the following batch were: 0.209, 0.193, 0.199. This gives a mean of 0.200 Bq and a rsd of ±3.2%. This is better than normally expected.

The samples were analyzed in 4 batches for radium-226. One control sample, prepared from the Amersham certified standard, was analyzed with each group. Two different

control standards were used, 1.20 Bq and 6.02 Bq. The results were: (1.20 Bq - 1.11,1.19) and (6.02 Bq - 5.94, 5.47). The percent difference from the standard for each sample was used to calculate a relative standard deviation of ±4.7%. This is within control.

Uranium analysis of the ash was performed in two batches. Six control standards (CANMET certified ore standards) were analyzed with each batch. For batch 1 the standard concentrations followed by the determined value were: 0.011 Bq (0.011); 0.062 Bq,(0.057); 0.126 Bq, (0.111); 0.615 Bq, (0.611); 1.22 Bq, (1.25); 12.9 Bq, (12.4). The rsd calculated from the percent differences is ±4.6%. In batch 2 the results were: 0.0017 Bq, (0.0012); 0.127 Bq, (0.140); 1.23 Bq, (1.25); 9.08 Bq, (8.90); 18.3 Bq, (18.1). The one standard at the detection limit (0.0017) was not used in calculating the relative standard deviation of ±3.6%. This is good performance.

DISCUSSION

Uranium is the only radioisotope determined that exhibits mean concentrations slightly above the detection limit (0.000013 Bq/g flesh, 0.0002 Bq/g bone). The mean values are 0.000015 Bq/g flesh and 0.00023 Bq/g bone for northern pike; 0.000015 Bq/g flesh and 0.00023 Bq/g bone for sucker; 0.000026 Bq/g flesh and 0.00057 Bq/g bone for whitefish. Only the whitefish values are significantly above the detection limit. All radiochemical measurements on fish performed by our laboratory have consistently shown whitefish and suckers to have higher levels than northern pike and lake trout. Much of this difference can be attributed to the feeding habits of the different species. Whitefish and suckers tend to be bottom feeders. Most of the radionuclides entering lakes become adsorbed onto suspended particulates which eventually settle to the bottom. Consequently, the lake sediments will have much higher radionuclide concentrations than the water. Bottom feeders will ingest organisms and sediments that contain these elevated levels which results in higher uptakes than northern pike and lake trout. The main exception to this bottom deposition is uranium. It exists primarily as the highly soluble uranyl ion (UO_2^{++}) and can be present in significant concentrations in the water. However, there is sufficient naturally occurring uranium in the sediments to produce the higher uptakes observed in the bottom feeders.

There is an interesting correlation between the dissolved uranium in lake water and the levels present in fish. This is shown in Figure 2. For lake water concentrations below 5 to 10 μg/L there is a linear relationship between the uranium in the water and that in the fish bone. As the water concentration increases above 10 μg/L this relationship becomes more and more nonlinear. If these high levels were extrapolated back to low water concentrations, the predicted fish concentrations would be orders of magnitude too high. A similar correlation has been observed for radium-226 (Martin et al). Some of the data used to prepare this log-log plot comes from Swanson (Beaverlodge Lake, Tailings Creek, Fredette Lake and Milliken Lake). The Langley Bay result is from Waite et al. In addition, data from Wollaston Lake (the lowest concentration) and McDonald Lake (near an active uranium operation) are included. The uranium concentration in the Lake Athabasca whitefish bone is almost identical to that found in Wollaston Lake whitefish (0.02 to 0.04 Bq/g). This would suggest that Lake Athabasca has a similar dissolved uranium concentration. The level of uranium in Wollaston lake (0.03 to 0.04 μg/l) cannot be measured by the usual uranium analytical techniques. The value reported was determined by ICP - Mass Spectrometry which has a detection limit of less than 0.005 μg/L. The results for Lake Athabasca reported by Waite et al (0.2 μg/L) was determined by laser fluorescence. This is at the detection limit for this method and it would not be possible to determine concentrations below 0.05 μg/L.

An attempt was made to estimate the actual concentration of radium-226 in fish flesh by calculating a typical uranium-238/radium-226 ratio from fish containing higher levels of both. For high levels of dissolved uranium in water this ratio was found to be approximately 10:1 or higher but as the dissolved uranium decreased the ratio appeared to approach 1:1. There was too much variation at the low end to make this a useful technique. An estimate of the radium-226 in the flesh would be to use one-half of the detection limit. This would result in a value of 0.000025 Bq/g. Holtzman gives an average daily dietary intake of radium-226 for North American adults of 0.05 Bq. Approximately 0.0075 to 0.015 Bq comes from meat, fish, poultry and dairy products. This means that 300 to 600 g of fish could be consumed daily and the total radium-226 intake would remain within the normal level. World wide the daily dietary intake of radium-226 varies between 0.022 to 0.15 Bq. Fish from Japan and India are reported to have levels of radium-226 varying between 0.0002 to 0.0006 Bq/g (Lalit and Ramachandran). From these comparisons it can be seen that the *estimated* level of radium-226 in Lake Athabasca fish would not pose a problem for human consumption. Another comparison can be made to the Canadian drinking water standard for Ra-226

(0.1 Bq/L). Consumption of 1 litre of water containing this amount of radium would be equivalent to 4 kg of Lake Athabasca fish flesh.

Lead-210 and polonium-210 are common trace radionuclides in marine and fresh water systems. The main source is from the radioactive decay of radon-222 which is constantly being emitted into the atmosphere from soil and rock. There is a constant flux of the two metallic decay products (Pb-210 and Po-210) being deposited on the earth and water surfaces. In water bodies, the two radionuclides are eventually incorporated into the bottom sediments. Consequently, these radionuclides are present in all aquatic organisms and fish. The levels measured in this study are mainly below the detection limit which would put them below those levels observed in other studies (Holtzman; Lalit and Ramachandran). Human consumption of Lake Athabasca fish would be safe with respect to the observed levels of these radionuclides.

The normal human, daily dietary intake of uranium varies between 0.015 to 0.075 Bq. The levels observed in the fish flesh vary from 0.00002 to 0.00003 Bq/g. Daily consumption of 0.5 to 2.5 kg of Lake Athabasca fish would not change the normal dietary intake of uranium. The current Canadian drinking water standard for dissolved uranium is 0.6Bq/L (50 μg/L). At this level, 1 litre of water would correspond to over 5 kg of fish flesh.

The levels of thorium isotopes observed in the fish are at or below the detection limit. The only isotope that does show some positive values is thorium-230. This isotope is in the uranium-238 decay series and occurs naturally in lake sediments. It is most probable that the level in Lake Athabasca fish is identical to that found in similar northern Saskatchewan lakes. Thorium isotopes are very insoluble and their uptake is always much less than for uranium, radium and lead-210 when a natural source is involved.

CONCLUSIONS

This study has shown that there are no abnormal levels of naturally occurring radionuclides in these northern pike, suckers and whitefish from Lake Athabasca. The levels present are equivalent to lowest found in fish from uncontaminated northern Saskatchewan lakes. Some of the smaller lakes in the vicinity of Lake Athabasca which have not been exposed to uranium mine-mill operations have natural levels of uranium much higher than is indicated for Lake Athabasca. In fact, these other lakes have uranium levels similar to those found in the South Saskatchewan and many other rivers throughout the world. The safety of eating fish from these rivers, with respect to their naturally occurring radioisotope content, has never been a concern.

The levels of radionuclides that would be contributed to a normal human diet from eating these fish would not change the normal daily intake. As has been pointed out, 4 to 5 kg of this fish flesh would contain the equivalent of 1 litre of water at the Canadian drinking water standards for uranium and radium-226.

The biological examination of the fish samples has shown no abnormalities or conditions other than those typically seen in Northern Saskatchewan fish.

BIBLIOGRAPHY

Balagus P, de Vries A and Green JE (1993). Collection of Fish from the Traditional Winter Fishery on the Peace-Athabasca Delta during February 1993. The Delta Environmental Group Ltd., Calgary, AB. Northern River Basins Study Project 3118-B2

Holtzman RB (1980). Normal Dietary Levels of Radium-226, Radium-228, Lead-210, and Polonium-210 for Man. Natural Radiation Environment III, Symposium held at Houston, Texas, April 23-28, 1978. Available as CONF-780422 from NTIS, U S Dept. of Commerce, Springfield, VA 22161

Holtzman RB, Urnezis PW, Padova A and Bobula CM (1979). Contamination of the Human Food Chain by Uranium Mill Tailings Piles. Argonne National Laboratory, Argonne, IL. Available as NUREG/CR-0758 from NTIS, U S Dept. of Commerce, Springfield, VA 22161

Lalit BY and Ramachandran TV (1980). Natural Radioactivity in Indian Foodstuffs. Natural Radiation Environment III, Symposium held at Houston, Texas, April 23-28, 1978. Available as CONF-780422 from NTIS, U S Dept. of Commerce, Springfield, VA 22161

LéTourneau C (1987). Transfer of Radionuclides of the Uranium and Thorium Decay Chains in Aquatic and Terrestrial Environments. Atomic Energy Control Board, Report INFO-0237(E), Ottawa, ON K1P 5S9.

Martin SS, Helm WT and Travis CC (1967). Accumulation of Ra-226 in Two Aquatic Ecosystems. National Symposium on Radioecology, Held at Ann Arbor, MI, May 15-17, 1967. Available from U S Atomic Energy Commission.

Ruggles RG and Rowley WJ (1978). A Study of Water Pollution in the Vicinity of the Eldorado Nuclear Limited Beaverlodge Operation 1976 and 1977. Environmental Protection Service, Fisheries and Environment Canada, Report EPS 5-NW-78-10, Edmonton, Alberta T5K 2J5

Swanson Stella (1982). Levels and Effects of Radionuclides in Aquatic Fauna of the Beaverlodge Area (Saskatchewan). Saskatchewan Research Council Publication Number C-806-5-E-82, Saskatoon, Saskatchewan S7N 2X8.

Waite DT, Joshi SR and Sommerstad H (1988). The Effect of Uranium Mine Tailings on Radionuclide Concentrations in Langley Bay, Saskatchewan, Canada. Arch. Environ. Contam. Toxicol. **17**, 373-380.

TABLE 1
ANALYTICAL DATA for WHITEFISH

Sample	% Ash		Polonium-210 Bq/g		Lead-210 Bq/g		Radium-226 Bq/g		Thorium-228 Bq/g		Thorium-230 Bq/g		Thorium-232 Bq/g		Uranium Bq/g	
	Flesh	Bone	Flesh	Bone	Flesh	Bone	Flesh	Bone	Flesh	Bone	Flesh	Bone	Flesh	Bone	Flesh	Bone
PO-01-WH	1.08	15.26	<0.0003	<0.0005	<0.001	<0.002	<0.00005	0.0008							0.00003	0.0020
PO-02-WH	1.14	11.47	<0.0003	<0.0005	<0.001	<0.002	<0.00005	0.0008							0.00001	0.0006
PO-07-WH	1.38	17.57	<0.0003	0.001	<0.001	<0.002	<0.00005	0.0009	<0.0001	<0.0015	0.0008	<0.0015	<0.0001	<0.0015	0.00004	0.0007
PO-10-WH	1.73	19.78	<0.0005	<0.001	<0.002	<0.004	<0.00005	<0.0008	<0.0001	<0.0015	<0.0001	0.0067	<0.0001	<0.0015	0.00003	<0.0002
PO-11-WH	1.12	16.67	<0.0003	<0.001	<0.001	<0.004	<0.00005	<0.0008							0.00001	0.0006
PO-26-WH	1.00	13.66	<0.0003	<0.0005	<0.001	<0.002	<0.00005	0.001							<0.00001	0.0010
PO-27-WH	1.19	13.35	<0.0003	<0.0005	<0.001	<0.002	<0.00005	<0.0008							<0.00001	0.0003
PO-32-WH	1.46	18.33	0.001	0.003	<0.001	<0.004	<0.00005	<0.0008	<0.0001	<0.0015	<0.0001	0.0033	<0.0001	<0.0015	0.00001	<0.0002
PO-34-WH	1.39	17.13	0.0004	0.001	<0.001	<0.002	<0.00005	<0.0008	<0.0001	0.002	0.0003	<0.0015	<0.0001	<0.0015	<0.00001	0.0006
PO-36-WH	1.22	15.55	<0.0003	0.004	<0.001	<0.002	<0.00005	<0.0008	<0.0001	<0.0015	0.0002	<0.0015	<0.0001	<0.0015	0.00005	0.0004
SH-05-WH	1.46	16.7	<0.0003	<0.0005	<0.001	<0.002	<0.00005	<0.0008	<0.0001	<0.0015	0.0002	<0.0015	0.0002	<0.0015	0.00004	0.0006
SH-09-WH	1.12	8.79	0.0002	<0.0003	<0.0005	<0.001	<0.00005	<0.0008							0.00001	0.0004
SH-10-WH	1.29	14.14	0.0005	<0.0005	<0.001	<0.002	<0.00005	0.001	<0.0001	<0.0015	<0.0001	<0.0015	<0.0001	<0.0015	0.00004	<0.0002
SH-11-WH	1.22	14.78	0.0001	0.0003	<0.0005	<0.001	<0.00005	<0.0008							0.00005	<0.0002
SH-12-WH	1.57	16.65	<0.0003	<0.0005	<0.001	<0.002	<0.00005	<0.0008	<0.0001	<0.0015	<0.0001	0.0055	<0.0001	<0.0015	0.00006	0.0006
SH-14-WH	1.01	8.98	<0.0003	<0.0005	<0.001	0.004	<0.00005	<0.0008							0.00001	0.0003
SH-15-WH	1.19	13.46	<0.0001	<0.0003	<0.0005	<0.001	<0.00005	0.0008							0.00003	0.0010
SH-16-WH	1.49	15.36	<0.0003	<0.0005	<0.001	<0.002	<0.00005	<0.0008	<0.0001	<0.0015	<0.0001	0.0015	<0.0001	<0.0015	0.00009	0.0009
SH-19-WH	1.40	16.73	<0.0003	<0.0005	<0.001	<0.002	<0.00005	0.0008	<0.0001	<0.0015	<0.0001	<0.0015	<0.0001	<0.0015	0.00001	0.0006
SH-20-WH	1.00	9.29	<0.0003	<0.0005	<0.001	<0.002	<0.00005	<0.0008							<0.00001	0.0004

TABLE 2

ANALYTICAL DATA for SUCKERS

Sample	% Ash		Polonium-210 Bq/g		Lead-210 Bq/g		Radium-226 Bq/g		Uranium Bq/g	
	Flesh	Bone	Flesh	Bone	Flesh	Bone	Flesh	Bone	Flesh	Bone
PO-05-SU	1.36	17.17	<0.0003	<0.0005	<0.001	<0.002	<0.00005	0.001	0.00004	0.0002
PO-09-SU	0.96	11.95	<0.0003	<0.0005	<0.001	<0.002	<0.00005	0.001	<0.00001	<0.0002
PO-16-SU	1.71	17.59	<0.0003	<0.0005	<0.001	0.004	<0.00005	0.001	0.00002	0.0003
PO-22-SU	1.13	10.81	<0.0003	<0.0005	<0.001	0.004	<0.00005	0.001	<0.00001	<0.0002
PO-28-SU	1.43	14.23	<0.0003	<0.0005	<0.001	0.003	<0.00005	0.0008	<0.00001	0.0004
PO-43-SU	1.08	11.17	0.0006	<0.001	0.001	0.003	<0.00005	<0.0008	<0.00001	<0.0002
SH-28-SU	0.92	13.35	<0.0001	<0.0003	<0.0005	<0.001	<0.00005	0.001	<0.00001	0.0004
SH-29-SU	1.59	12.59	0.0001	<0.0005	<0.0005	<0.002	<0.00005	<0.0008	0.00002	<0.0002
SH-30-SU	1.18	14.2	<0.0001	0.0004	<0.0005	<0.001	<0.00005	<0.0008	0.00001	0.0005
SH-39-SU	1.17	11.29	<0.0001	0.001	<0.0005	<0.002	<0.00005	0.0008	0.00002	<0.0002
SH-42-SU	1.51	17.6	<0.0001	<0.0003	<0.0005	<0.001	<0.00005	<0.0008	0.00004	0.0004
SH-48-SU	1.21	10.2	<0.0001	0.0004	<0.0005	<0.001	<0.00005	0.001	<0.00001	<0.0002

TABLE 3
ANALYTICAL DATA for NORTHERN PIKE

Sample	% Ash		Lead-210 Bq/g		Radium-226 Bq/g		Uranium Bq/g	
	Flesh	Bone	Flesh	Bone	Flesh	Bone	Flesh	Bone
PO-08-PI	0.97	20	<0.001	<0.002	0.0001	<0.0008	<0.00001	<0.0002
PO-12-PI	1.20	15.23	<0.0005	<0.001	<0.00005	<0.0008	0.00001	0.0002
PO-18-PI	0.82	15.45	<0.0005	<0.001	<0.00005	<0.0008	0.00006	0.0004
PO-19-PI	1.22	19.62	<0.0005	<0.001	<0.00005	<0.0008	0.00002	<0.0002
PO-20-PI	1.02	13.45	<0.0005	<0.001	<0.00005	<0.0008	0.00001	0.0004
PO-21-PI	1.07	11.49	<0.0005	<0.001	<0.00005	<0.0008	0.00001	0.0003
PO-23-PI	1.10	15.27	<0.0005	<0.001	<0.00005	<0.0008	0.00002	0.0002
PO-37-PI	1.29	15.36	<0.001	<0.002	<0.00005	<0.0008	<0.00001	0.0002
PO-38-PI	1.01	19.27	<0.0005	<0.001	<0.00005	<0.0008	0.00005	0.0002
PO-39-PI	1.14	19.46	<0.001	<0.002	<0.00005	<0.0008	<0.00001	0.0004
SH-23-PI	1.07	16.73	<0.0005	<0.001	<0.00005	<0.0008	0.00002	0.0002
SH-24-PI	1.06	23.75	<0.001	<0.002	<0.00005	<0.0008	<0.00001	0.0004
SH-25-PI	1.10	18.61	<0.0005	<0.001	<0.00005	<0.0008	0.00001	<0.0002
SH-31-PI	1.00	11.63	<0.0005	<0.001	<0.00005	<0.0008	0.00002	0.0002
SH-34-PI	1.12	13.78	<0.0005	<0.001	<0.00005	<0.0008	0.00002	<0.0002
SH-35-PI	0.94	13.64	<0.001	<0.002	<0.00005	<0.0008	<0.00001	<0.0002
SH-41-PI	1.01	16.18	<0.001	<0.002	<0.00005	<0.0008	<0.00001	0.0002
SH-46-PI	1.16	19	<0.001	<0.002	<0.00005	<0.0008	<0.00001	<0.0002
SH-47-PI	0.95	19.83	<0.0005	<0.001	<0.00005	<0.0008	<0.00001	<0.0002
SH-49-PI	0.95	18.84	<0.0005	<0.001	<0.00005	<0.0008	<0.00001	0.0006

TABLE 4
QC Analysis of Duplicates

Sample	Type	Radium-226 Bq/g		Thorium-228 Bq/g		Thorium-230 Bq/g		Thorium-232 Bq/g		Uranium µg/g	
		Result 1	Result 2	Result 1	Result 2	Result 1	Result 2	Result 1	Result 2	Result 1	Result 2
PO-02-WH	Bone	0.0008	0.0008								
PO-07-WH	Bone									0.05	0.07
PO-26-WH	Bone									0.09	0.07
PO-34-WH	Bone			0.002	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015		
PO-34-WH	Flesh									<0.001	<0.001
PO-36-WH	Bone			<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015		
SH-12-WH	Bone									0.12	0.03
SH-16-WH	Flesh									0.009	0.006
PO-12-PI	Bone	<0.0008	<0.0008								
PO-19-PI	Flesh	<0.00005	<0.00005								
PO-39-PI	Bone									0.06	<0.02
SH-24-PI	Bone									0.02	0.05
SH-46-PI	Bone	<0.0008	<0.0008							0.015	<0.015
PO-05-SU	Bone									0.015	0.015
PO-22-SU	Bone									<0.015	0.015
SH-28-SU	Bone	0.001	0.001							0.04	0.03
SH-30-SU	Bone									0.045	0.045
SH-42-SU	Flesh	<0.00005	<0.00005								
SH-42-SU	Bone									0.035	0.035

TABLE 5

QC Data for Concentrations Near the Detection Limit
SRC Radiochemical Laboratory
For the Period 1986 - 1992

Isotope	Detection Limit, Bq	Lab Control Standards			Samples Analyzed in Duplicate		
		Conc., Bq	Number of Determ'ns	Standard Deviation, Bq	Conc. Range, Bq	Number of Duplicates	Standard Deviation, Bq
Ra-226	0.005	0.044	107	±0.007	0.01 - 0.10	67	±0.004
Uranium	0.001	0.01	104	±0.0015	0.005 - 0.10	215	±0.001
	0.001	0.02	163	±0.002			
Pb-210	0.02	0.15	257	±0.018	0.02 - 0.50	182	±0.03
Po-210	0.005	0.15	234	±0.014	0.01 - 0.15	117	±0.013
Th-isotopes	0.01	0.20	677	±0.016	0.01 - 0.10	78	±0.005

TABLE 6

Hook Point Sample Site
Fish Specimen Measurements

Species	Sample #	Age	Sex	Length cm	Weight kg
Pike	PO-08-PI	5	F	80.4	3.43
Pike	PO-12-PI	11	F	83.9	4.66
Pike	PO-18-PI	4	F	71.9	2.72
Pike	PO-19-PI	5	F	79.0	3.07
Pike	PO-20-PI	6	F	86.4	6.01
Pike	PO-21-PI	12	F	83.2	4.56
Pike	PO-23-PI	9	F	96.4	7.81
Pike	PO-37-PI	7	M	80.2	4.14
Pike	PO-38-PI	10	F	87.6	5.79
Pike	PO-39-PI	7	M	71.2	2.75
Whitefish	PO-01-WH	11	M	43.2	1.23
Whitefish	PO-02-WH	12	M	44.8	1.48
Whitefish	PO-07-WH	9	F	44.8	1.22
Whitefish	PO-10-WH	9	F	48.7	0.75
Whitefish	PO-11-WH	13	F	44.0	1.11
Whitefish	PO-26-WH	13	M	43.8	1.23
Whitefish	PO-27-WH	12	M	43.6	1.17
Whitefish	PO-32-WH	11	M	49.7	1.88
Whitefish	PO-34-WH	14	M	46.1	1.43
Whitefish	PO-36-WH	10	F	44.9	1.33
White Sucker	PO-05-SU	10	F	48.0	1.70
White Sucker	PO-09-SU	10	M	41.5	1.09
White Sucker	PO-16-SU	10	M	42.4	1.08
White Sucker	PO-22-SU	11	M	44.0	1.27
White Sucker	PO-28-SU	6	F	41.4	0.88
White Sucker	PO-43-SU	4	F	34.4	0.55

TABLE 7

Bustard Island Sample Site
Fish Specimen Measurements

Species	Sample #	Age	Sex	Length cm	Weight kg
Pike	SH-23-PI	8	F	78.1	3.46
Pike	SH-24-PI	9	F	88.4	5.01
Pike	SH-25-PI	7	F	91.5	4.16
Pike	SH-31-PI	11	F	94.6	7.41
Pike	SH-34-PI	7	F	91.3	5.81
Pike	SH-35-PI	18	M	81.4	3.86
Pike	SH-41-PI	8	F	78.5	3.48
Pike	SH-46-PI	9	F	78.2	2.27
Pike	SH-47-PI	11	F	92.6	6.66
Pike	SH-49-PI	10	F	89.7	6.31
Whitefish	SH-05-WH	9	F	42.9	1.26
Whitefish	SH-09-WH	11	M	40.7	1.06
Whitefish	SH-10-WH	8	F	44.5	1.39
Whitefish	SH-11-WH	13	F	40.8	0.99
Whitefish	SH-12-WH	13	F	42.2	1.25
Whitefish	SH-14-WH	11	F	41.6	1.01
Whitefish	SH-15-WH	9	M	40.9	0.96
Whitefish	SH-16-WH	12	F	42.5	1.15
Whitefish	SH-19-WH	12	F	42.2	1.16
Whitefish	SH-20-WH	11	F	42.1	1.07
White Sucker	SH-28-SU	6	F	41.6	1.17
White Sucker	SH-29-SU	5	M	36.1	0.72
White Sucker	SH-30-SU	6	F	40.3	0.93
White Sucker	SH-39-SU	5	F	35.8	0.60
White Sucker	SH-42-SU	8	F	47.4	1.65
Longnose Sucker	SH-48-SU	8	F	44.2	1.16

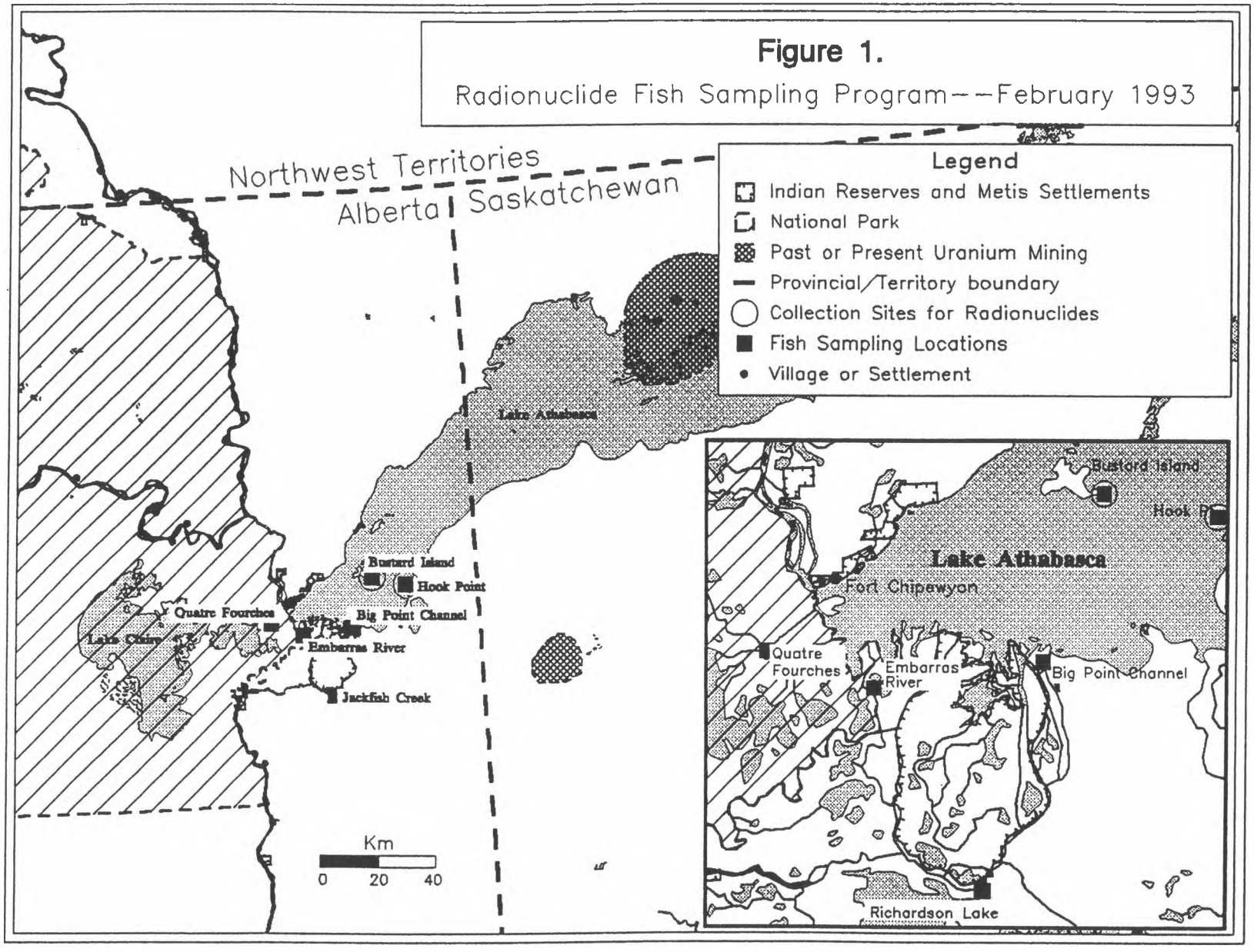
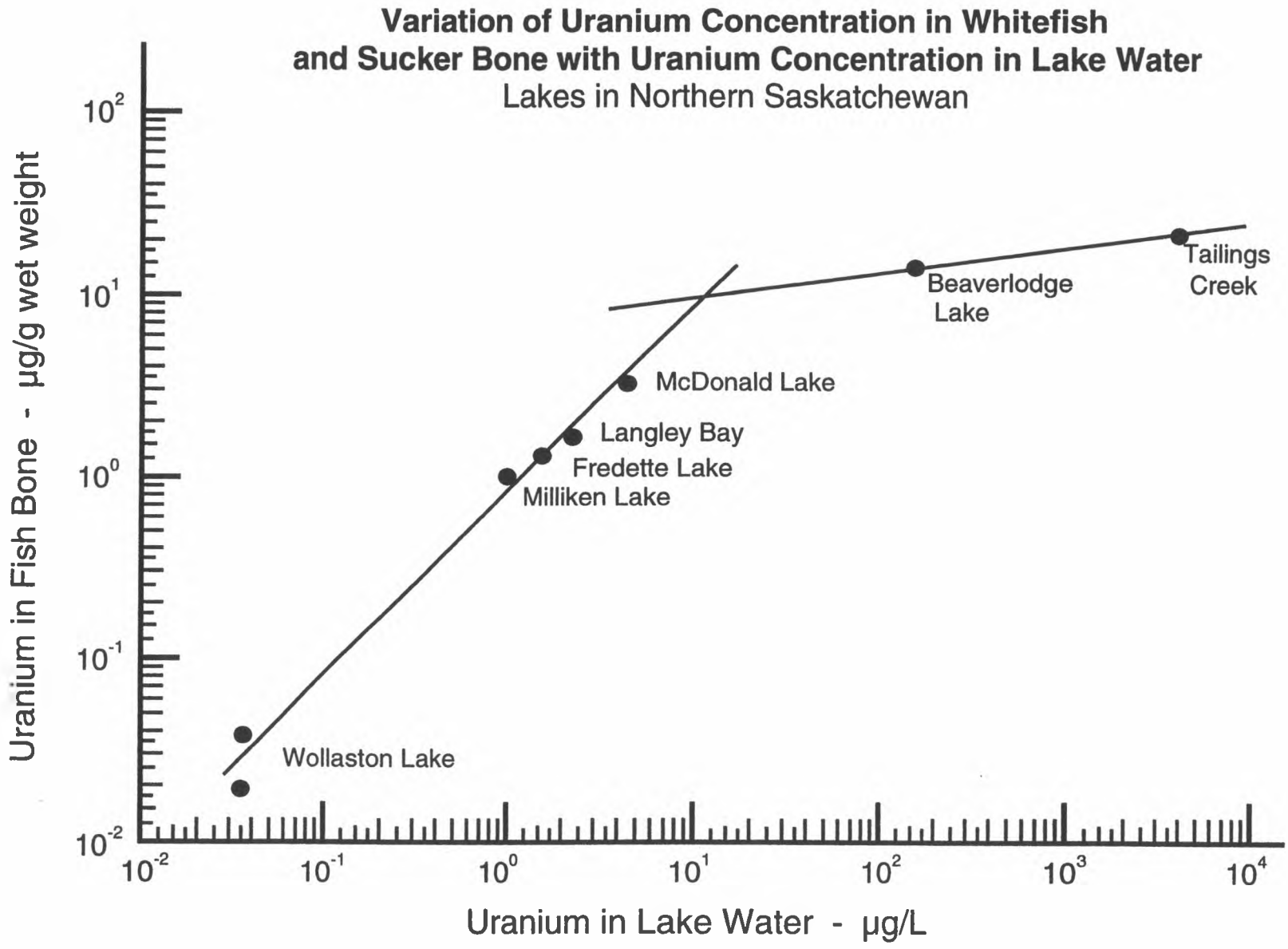


Figure 1.
Radionuclide Fish Sampling Program--February 1993
Northwest Territories
Alberta
Saskatchewan
Legend
Indian Reserves and Metis Settlements
National Park
Past or Present Uranium Mining
Provincial/Territory boundary
Collection Sites for Radionuclides
Fish Sampling Locations
Village or Settlement
Lake Athabasca
Bustard Island
Hook Point
Quatre Fourches
Big Point Channel
Lake Claire
Embarras River
Jackfish Creek
Km
0 20 40
Lake Athabasca
Fort Chipewyan
Richardson Lake

FIGURE 2


Variation of Uranium Concentration in Whitefish
and Sucker Bone with Uranium Concentration in Lake Water
Lakes in Northern Saskatchewan
Uranium in Fish Bone - µg/g wet weight
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
Tailings Creek
Beaverlodge Lake
McDonald Lake
Langley Bay
Fredette Lake
Milliken Lake
Wollaston Lake
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Uranium in Lake Water - µg/L

APPENDIX 1

GROSS PATHOLOGY EXAMINATION

(GROSS PATHOLOGY SHEETS FOR INDIVIDUAL FISH AVAILABLE AT NORTHERN RIVER BASINS STUDY OFFICE)

3118-B3.

Saskatchewan
Research Council

15 Innovation Blvd. Saskatoon, Saskatchewan Canada S7N 2X8 Phone: (306) 933-5400 Fax: (306) 933-7446

May 13, 1993

Mr. Greg Wagner
Project Liaison Officer
Office of the Science Director
Northern River Basins Study
690 Standard Life Centre
10405 Jasper Avenue
Edmonton, AB T5J 3N4

COPY

Dear Mr. Wagner:

Please find enclosed the completed Gross Pathology and Examination Sheets for Project 3118-B3 Winter Subsistence Fishery-Radionuclide Analysis. I observed nothing in the samples which I have not typically seen in other specimens from water bodies in the Athabasca Sandstone Basin.

All the lake whitefish were infected with pearly cysts on their digestive tracts. Hearts frequently had sand grain sized nodules on the ventricle. *Triaenophorus sp* cysts in the flesh ranged from 0 to 8 (PO-26-LW).

Approximately half the northern pike females showed reabsorption of ova. All fish had large numbers of *Triaenophorus sp* adults in their guts.

A few white suckers had occurrences of black spot (probably *Neascus* sp) on fins and ventral areas. Fish sample (SH-48-SU) was a longnose sucker.

If I can be of any more assistance on this matter please call (306) 933-8177 or drop in the next time you are at NHRI. Thanks for your patronage.

Yours truly,

Barry Paquin, Technologist
Aquatic Ecosystems
Environment Technology Division

Enclosure

BP:ymw

APPENDIX 2

PROJECT TERMS OF REFERENCE

NORTHERN RIVER BASINS STUDY

TERMS OF REFERENCE

Project 3118-B3: Winter Subsistence Fishery - Radionuclide Analyses

I. Objective

In February 1993, the Northern River Basins Study collected fish from six traditional harvest areas located on Lake Athabasca and in the Peace-Athabasca Delta. These collections were made to determine the extent, if any, of 1) chemical contaminants associated with downstream industrial developments; and, 2) radionuclides associated with uranium mining activity around Lake Athabasca in fish species commonly consumed by local residents. The purpose of this project is to carry out radionuclide analyses on fish collected from two sites on Lake Athabasca.

II. Requirements

The Northern River Basins Study will be supplying the contractor with 52 fish collected from two sites on Lake Athabasca in February 1993 (Appendix A). The following analyses are to be performed on these fish:

1) The sex of each fish is to be determined and recorded.

2) Ageing structures (Appendix B) are to be removed from each fish, stored in appropriately labelled containers, frozen and returned frozen to the Project Liaison Officer (Greg Wagner, Office of the Science Director, Northern River Basins Study, 690 Standard Life Centre, 10405 Jasper Avenue, Edmonton, Alberta. T5J 3N4; phone: (403) 427-1742, fax: (403) 427-1742) for further analysis.

3) Information on gross pathology as indicated in Appendix C is to be recorded for each species.

4) Gut contents of each fish are to be removed, appropriately labelled and preserved in such a fashion that they could be used for future radionuclide analyses. Based on instructions from the Project Liaison Officer, gut contents are to be held by the contractor for further radionuclide analyses or returned to the Project Liaison Officer for archiving or analysis related to contaminant or food chain studies.

5) Each fish is to be skinned and prepared such that separate radionuclide analyses can be performed on the flesh and bones of each fish. Wet weights and percent ash are to be recorded for all samples.

6) The following radionuclide analyses are to be performed on all suckers and five whitefish from each of the two collection sites (to be selected by the contractor):

a) Radium^{226};

b) Lead^{210};

c) Uranium (by delayed neutron counting); and,

d) Thorium Isotopes (Thorium^{228}, Thorium^{230}, Thorium^{232}).

Based on the results of the Lead^{210} analysis, the contractor will recommend to the Project Liaison Officer the need to analyze for Polonium^{210}. The Project Liaison Officer will take the recommendations of the contractor under consideration and will direct the contractor as to proceeding or not proceeding with Polonium^{210} analysis.

7) Based on the results of 6 above, the contractor will provide the Project Liaison Officer with a written recommendation regarding the need to carry out Thorium Isotope analysis on the remaining fish samples. The Project Liaison Officer will take the recommendations of the contractor under advisement and direct the contractor to proceed or not proceed with Thorium isotope analysis on the remaining fish samples.

8) The contractor is to carry out the following radionuclide analyses on the flesh and bone samples of each of the remaining fish:

a) Radium^{226};

b) Lead^{210};

c) Uranium (by delayed neutron counting); and,

d) possibly, Thorium Isotopes (Thorium^{228}, Thorium^{230}, Thorium^{232}).

Based on the results of the Lead^{210} analysis, the contractor will recommend to the Project Liaison Officer the need to analyze for Polonium^{210}. The Project Liaison Officer will take the recommendations of the contractor under

consideration and will direct the contractor as to proceeding or not proceeding with Polonium^{210} analysis.

III. Reporting Requirements

1) Submit ten copies of the draft report to the Project Liaison Officer by March 31st, 1993. The draft report is to include information on the following: sample handling, processing and analytical methods, quality assurance/quality control measures (including the results of duplicate samples and analyses of standard materials - indicate from whom the standard material was obtained), results of the radionuclide analyses, including the basis for proceeding or not proceeding with Polonium^{210} and Thorium isotope analyses, and a discussion of the results with regards to the results of other radionuclide studies in the Lake Athabasca area, and the results of radionuclide testing at other uranium mining areas.

2) Three weeks after the receipt of review comments, submit ten cerlox bound copies and two unbound, camera-ready copies of the final report to Project Liaison Officer. The final report is to include an executive summary, acknowledgements section, table of contents, list of tables (if appropriate), list of figures (if appropriate) and an appendix containing the Terms of Reference for this project. An electronic copy of the final report, in Word Perfect 5.1 format, is to be submitted to the Project Liaison Officer along with the final report. Data presented in tables, figures and appendices of the final report is to be placed in dBase IV files and submitted to the Project Liaison Officer along with the final report.

APPENDIX A
NORTHERN RIVER BASINS STUDY FISH COLLECTIONS FOR RADIONUCLIDE ANALYSES

Table I: Fish Collections from Bustard Island Site, Lake Athabasca. Sampling Dates: February 12, 14 and 16, 1993.		
Species	Sample Number	Length (cm)
Pike	SH-31-PI	94.6
Pike	SH-47-PI	92.6
Pike	SH-25-PI	91.5
Pike	SH-34-PI	91.3
Pike	SH-49-PI	89.7
Pike	SH-24-PI	88.4
Pike	SH-35-PI	81.4
Pike	SH-41-PI	78.5
Pike	SH-46-PI	78.2
Pike	SH-23-PI	78.1
Whitefish	SH-10-WH	44.5
Whitefish	SH-05-WH	42.9
Whitefish	SH-16-WH	42.5
Whitefish	SH-19-WH	42.2
Whitefish	SH-12-WH	42.2
Whitefish	SH-20-WH	42.1
Whitefish	SH-14-WH	41.6
Whitefish	SH-15-WH	40.9
Whitefish	SH-11-WH	40.8
Whitefish	SH-09-WH	40.7
Sucker	SH-28-SU	41.6
Sucker	SH-29-SU	36.1
Sucker	SH-30-SU	40.3
Sucker	SH-39-SU	35.8
Sucker	SH-42-SU	47.4
Sucker	SH-48-SU	44.2

Table II: Fish Collections from Hook Point Site, Lake Athabasca. Sampling Dates: February 12, 14 and 16, 1993.		
Species	Sample Number	Length (cm)
Pike	PO-23-PI	96.4
Pike	PO-38-PI	87.6
Pike	PO-20-PI	86.4
Pike	PO-12-PI	83.9
Pike	PO-21-PI	83.2
Pike	PO-08-PI	80.4
Pike	PO-37-PI	80.2
Pike	PO-19-PI	79.0
Pike	PO-18-PI	71.9
Pike	PO-39-PI	71.2
Whitefish	PO-32-WH	49.7
Whitefish	PO-10-WH	48.7
Whitefish	PO-34-WH	46.1
Whitefish	PO-36-WH	44.9
Whitefish	PO-07-WH	44.8
Whitefish	PO-02-WH	44.8
Whitefish	PO-11-WH	44.0
Whitefish	PO-26-WH	43.8
Whitefish	PO-27-WH	43.6
Whitefish	PO-01-WH	43.2
Sucker	PO-05-SU	48.0
Sucker	PO-09-SU	41.5
Sucker	PO-16-SU	42.4
Sucker	PO-22-SU	44.0
Sucker	PO-28-SU	41.4
Sucker	PO-43-SU	34.4

APPENDIX B
FISH AGEING STRUCTURES

SOURCE: Mackay, W. C., G.R. Ash and H. J. Norris (eds.). 1990. Fish Ageing Methods for Alberta. R. L. & L. Environmental Services Ltd. in association with Alberta Fish and Wildlife Division and University of Alberta, Edmonton. 113 p.

LAKE WHITEFISH

(*Coregonus clupeaformis*)

Key Contributors: Dave Berry and Dick Brown

Preferred Structure:

Slow-growing fish - sagittal otoliths (lethal).

Fast-growing fish - scales (non-lethal) from the left side between the front edge of the dorsal fin and the lateral line. Take 10-15 scales. Old fish may be difficult to age with scales. Some populations in which problems have been encountered using scales include Lesser Slave Lake (slow growth), Lake Athabasca (migrate in lake and river habitats), Wabamun Lake (possibly influenced by heated effluent), and probably some southern populations with access to irrigation canals.

Secondary Structures:

Use pelvic fin rays for non-lethal samples but sagittal otoliths are preferred. The latter may require grinding, or breaking and toasting. Opercular bones also appear to be promising structures for ageing lake whitefish.

Time of Annulus Formation:

May - June.

References:

Barnes, M.A., and G. Power. 1984. A comparison of otolith and scale ages for western Labrador lake whitefish. Environmental Biology of Fishes 10: 297-299.

Bond, W.A., and R.N. Erickson. 1985. Life history studies of anadromous coregonid fishes in two freshwater lake systems on the Tuktoyaktuk Peninsula, Northwest Territories. Can. Tech. Rep. Fish. Aquat. Sci. 1336: vii + 61 p.

Eckman, R., and P. Rey. 1987. Daily increments on the otoliths of larval and juvenile *Coregonus* spp., and their modification by environmental factors. Hydrobiologia 148(2):137-144.

Hart, J.L. 1931. The growth of the whitefish, *Coregonus clupeaformis* (Mitchill). Contrib. Can. Biol. Fish., N.S. 6:427-444.

Kennedy, W.A. 1953. Growth, maturity, fecundity, and mortality in the relatively unexploited whitefish, *Coregonus clupeaformis*, of Great Slave Lake. J. Fish. Res. Board Can. 10:413-441.

_____. 1963. Growth and mortality of whitefish in three unexploited lakes in northern Canada. J. Fish. Res. Board Can. 20: 265-272.

Mills, K.H., and R.J. Beamish. 1980. Comparison of fin ray and scale age determinations for lake whitefish (*Coregonus clupeaformis*) and their implications for estimates of growth and annual survival. Can. J. Fish. Aquat. Sci. 37:534-544.

Power, G. 1978. Fish population structure in Arctic lakes. J. Fish. Res. Board Can. 35 (1): 53-59.

Smale, M.A., and W.W. Taylor. 1987. Sources of back-calculation error in estimating growth of lake whitefish. p. 189-202. IN: R.C. Summerfelt and G.E. Hall (eds.). Age and Growth of Fish. Univ. of Iowa Press. Ames, Iowa. 544 p.

Van Oosten, J. 1923. The whitefishes (*Coregonus clupeaformis*). A study of the scales of whitefishes of known ages. Zoologica (N.Y.) 2: 381-412.

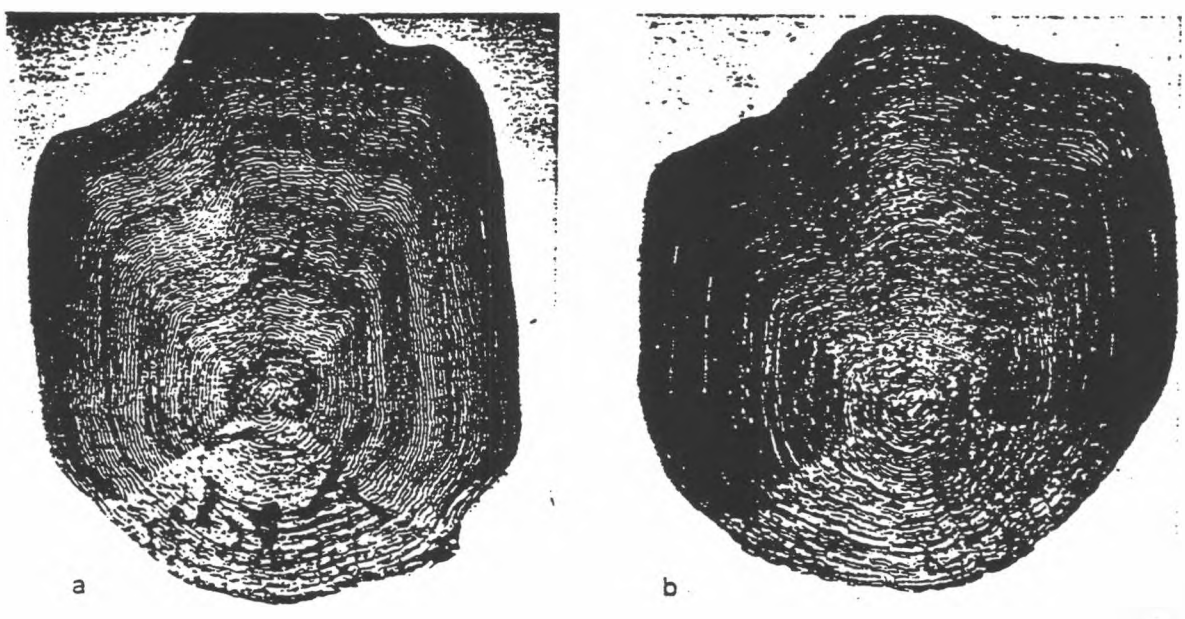


Plate 4. Scales from a five year old, fast growing, and an eight year old, slow growing, lake whitefish (August 25, 1979).

MOUNTAIN WHITEFISH

(*Prosopium williamsoni*)

Key Contributor: Wes English

Preferred Structure:

Scales (non-lethal) from left side between the dorsal fin and the lateral line. Take 10-15 scales. Thompson (1974) found that young mountain whitefish from the Sheep River, Alberta, had complete scale development when they reached a length of 50-65 mm. These fish grew to a length of 80 mm by mid-October. Larger (100 mm) young fish that were also caught were believed to have been migrating upstream from richer, warmer downstream waters. The mean back-calculated length from over 300 fish was 71 mm at first annulus.

Thompson (1974) found excellent agreement between scale and otolith readings for 30 fish between 200 and 415 mm in length.

Thompson's (1974) and Sigler's (1951) respective factors for converting from fork length to total length were 1.0936 and 1.0599, and from fork length to standard length were 0.9202 and 0.9099.

Secondary Structure:

Sagittal otolith (lethal). These may require grinding, or breaking and toasting. Fin rays may work for a non-lethal sample.

Time of Annulus Formation:

Thompson found that it was complete by the end of May and one fish had formed its annulus by April 24.

References:

Thompson, G.E. 1974. The ecology and life history of the mountain whitefish *Prosopium williamsoni* (Girard) in the Sheep River, Alberta. M.Sc. Thesis, Univ. of

Calgary, Alberta. Also printed as Fish. Res. Rep. No. 12. Alta. Fish and Wildl. Div.

Sigler, W.F. 1951. The life history and management of the mountain whitefish, *Prosopium williamsoni* (Girard) in Logan River, Utah. Bull. 347. Utah State Agr. Coll. Logan, Utah. 21 p.

Steffox, A.D. 1987. Spray Lakes Reservoir gill netting survey, September 1986. Alta. Fish and Wildl. Div. MS. Rep.

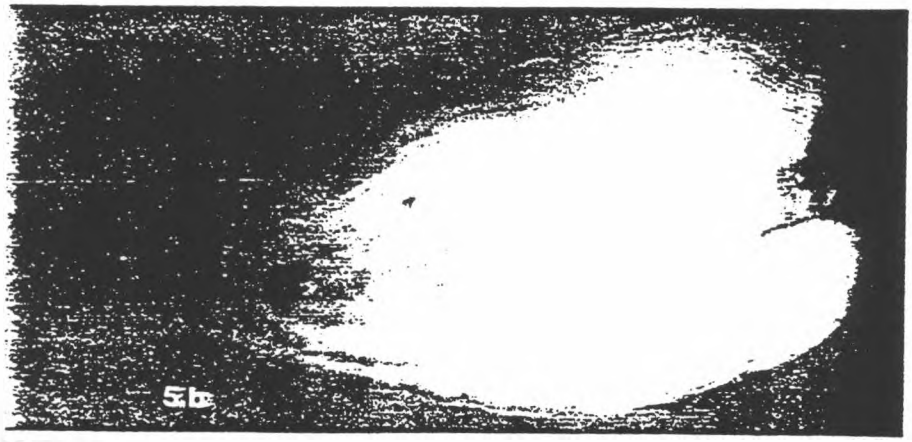


Plate 5. Otolith from 26 year old mountain whitefish from Spray Lakes September 17, 1986).

a. Cross-section of broken otolith

b. Otolith

Plate 6. Otolith from a five year old mountain whitefish from the Oldman River October 24, 1985.

NORTHERN PIKE

(*Esox lucius*)

Key Contributors: Jim Allan, Bill Mackay, and Daryl Watters

Preferred Structure:

Cleithrum (lethal sample) (Plate 12). However, after two weeks, dried cleithra lose their bleached white appearance and annuli become fuzzy; therefore, cleithra should be kept frozen until time of preparation for ageing. Accurate ageing by cleithra is definitely influenced by the experience of the reader.

First three left pelvic fin rays. Annuli are difficult to see on the fin rays of old fish as the outer edge of the ray becomes opaque.

Secondary Structure:

Fish judged to be three years of age or younger can be accurately aged using scales for comparison. Opercular bones and vertebrae (Applegate and Smith 1951) may also show clear annuli (Plate 12).

Time of Annulus formation:

late May - early June.

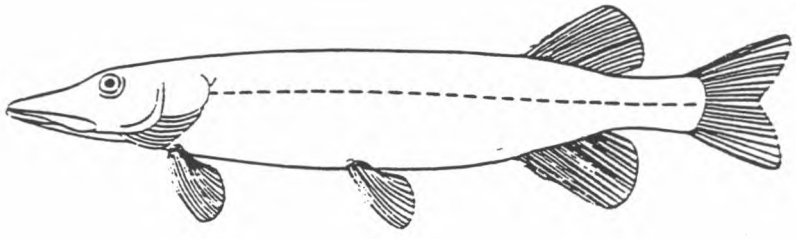


Plate 12. **Ageing structures for northern pike.**

a. cleithrum of a five year old northern pike. Note location of focus.

b. opercular bone of a five year old northern pike.

References:

Applegate, J., and L.L. Smith. 1951. The determination of age and rate of growth from vertebrae of the channel catfish, *Ictalurus lacustris punctatus*. Trans. Am. Fish. Soc. 80: 119-139.

Astanin, L.D. 1947. On the determination of the ages of fishes. Zoological J. 26: 287-288.

Casselman, J.M. 1974. Analysis of hard tissue of pike *Esox lucius* L. with special reference to age and growth. p. 13-27 IN: T.B. Bagenal (ed.). Ageing of fish. Proceedings of an International Symposium - Reading, England, 19-20 July, 1973. Unwin Brothers Ltd., Gresham Press, Surrey, England. 234 p.

Casselman, J.M. 1975. Cleithral method of determining age and growth of northern pike and other esocids. Proc. 37th Midwest Fish and Wildl. Conf., Dec. 7-10, 1975, Toronto, Ont.

Franklin, D.R., and C. Smith, Jr. 1960. Note on development of scale patterns in the northern pike, *Esox lucius* L. Trans. Am. Fish. Soc. 89 (1): 83.

Frost, W.E., and C. Kipling. 1959. The determination of the age and growth of pike (*Esox lucius* L.) from scales and opercular bones. J. Cons. Int. Explor. Mer. 24: 314-341.

_____. 1961. Some observations on the growth of pike, *Esox lucius*, in Windermere. International Assocation of Theoretical and Applied Limnology Proceedings 14: 776-781.

Harrison, E.J., and W.F. Hadley. 1979. A comparison of the use of cleithra to scales for age and growth studies. Trans. Am. Fish. Soc. 108: 452-456.

Healy, A. 1956. Fishes of Lough Rea, Co. Galway, Ireland. Pike and rudd with general conclusions. Salm. Trout Mag. 148: 246-249.

Johnson, L.D. 1971. Growth of known age muskellunge in Wisconsin. Wisc. Dep. of Nat. Res., Madison. Tech. Bull. # 49.

Makowecki, R. 1973. The trophy pike, *Esox lucius*, of Seibert Lake. M.Sc. Thesis, Univ. of Alta. 239 p.

Munro, W.R. 1957. The pike of Loch Choin. Freshwat. Salm. Fish. Res. (16): 16 p.

Williams, J.E. 1955. Determinations of age from the scales of northern pike (*Esox lucius* L.). Doctoral Dissertation Series, Pub. No. 12 668, Univ. Microfilms, Ann Arbor, Michigan.

SUCKERS

(Family Catostomidae)

Key Contributor: Jim O'Neil

This method was developed for white suckers but it works on longnose suckers and presumably would work on other species of suckers as well.

Preferred Structure:

Pectoral fin rays (proximal end). Focus is considered as first annulus. Fin rays are distinctly superior to scales for back-calculation. Fin ray sections can be preserved after viewing by wrapping in parafilm and returning to envelope. Pelvic fin rays have also been used, but the first annulus is often close to the centre of the ray, and difficult to identify.

Secondary Structure:

Scales are acceptable to about age 5 or 6. Remove scales from left side below anterior insertion of dorsal fin and above lateral line. Use scales for small fish (less than 100 mm fork length).

Time of Annulus Formation:

Completed in spring.

Plates not available. See fin ray plates from walleye but note that the annuli are not as distinct in suckers.

References:

Beamish, R.J. 1973. Determination of age and growth of populations of the white sucker (*Catostomus commersoni*) exhibiting a wide range in size at maturity. J. Fish Res. Board Can. 30: 607-616.

Beamish, R.J., and A.H. Harvey. 1969. Age determination in the white sucker. J. Fish. Res. Board Can. 26: 633-638.

Chalanchuk, S.M. 1984. Ageing a population of white sucker, *Catostomus commersoni*, by fin ray method. Can. Tech. Rep. Fish. Aquat. Sci. 1321: iv + 16 p.

Geen, G.H., T.G. Northcote, G.F. Hartman, and C.C. Lindsey. 1966. Life histories of two species of catostomid fishes in Sixteen Mile Lake, British Columbia, with particular reference to inlet stream spawning. J. Fish. Res. Board Can. 23: 1761-1788.

MacCrimmon, H.R. 1979. Comparative annulus formation on anatomical structures of the white sucker, *Catostomus commersoni* (Lacepède). Fish. Manage. 10 (3):123-128.

Ovchynnyk, M.M. 1965. On age determination with scales and bones of the white sucker, *Catostomus commersoni* (Lacepède). Zool. Anz. 175: 325-345.

Priegel, G.R. 1976. Age and growth of the white sucker in Lake Winnebago, Wisconsin. Trans. Wis. Acad. Sci. Arts. Lett. 64: 132-143.

Quinn, S.P., and M.R. Ross. 1982. Annulus formation by white suckers and the reliability of pectoral fin rays for ageing them. N. Am. J. Fish. Manage. 2:204-208.

Scidmore, W.J. and A.W. Glass. 1953. Use of the pectoral fin rays to determine age of the white sucker. Prog. Fish-Cult. 15:114-115.

Spoor, H. 1939. Age and growth of the sucker, *Catostomus commersoni* (Lacepède), in Muskellunge Lake, Vilas County, Wisconsin. Trans. of the Wis. Acad. Sci. 31: 457-505.

Stewart, N.A. 1926. Development, growth and food habits of the white sucker, *Catostomus commersoni* Le Sueur. U.S. Bur. of Fish. Bull. 42: 147-184.

Walton, B.D. 1979. The reproductive biology, early life history, and growth of white suckers (*Catostomus commersoni*) and longnose suckers (*C. catostomus*) in the Willow Creek - Chain Lakes system, Alberta. M.Sc. Thesis, Univ. of Alta., Edmonton, Alberta. 180 p.

APPENDIX C
EXAMINATION SHEETS
GROSS PATHOLOGY

NORTHERN RIVER BASINS STUDY
EXAMINATION SHEETS
GROSS PATHOLOGY

Appendix C

REVIEWER: _____ **PROCESSING DATE:** _____

SAMPLE NO.: _____ **LOCATION:** _____

SPECIES: _____ **SEX:** _____

GROSS EXTERNAL EXAMINATION

Skin: ( ) Normal ( ) Excessive mucus ( ) Abnormal Colour _____
( ) Lesions ( ) Single ( ) Multiple ( ) Closed
( ) Open ( ) Haemorrhagic ( ) Necrotic ( ) Ulcer
( ) Blister ( ) Tumour ( ) Lost Scales ( ) Abrasions

Location: _____

Wet mount/smear: _____

Eyes: ( ) Normal ( ) Exophthalmia ( ) Cataract ( ) Haemorrhagic
Fins: ( ) Opaque cornea ( ) Eroded ( ) Parasite ( ) Haemorrhagic

( ) Eroded _____ ( ) Deformed _____

Wet mount/smear: _____

Gills: ( ) Normal ( ) Pale ( ) Mottled ( ) Haemorrhagic
( ) Necrotic ( ) Excessive mucus ( ) Hyperplasia
( ) Telangiectasia ( ) Gas emboli ( ) Cysts
( ) Large Parasites _____ ( ) Fungus Visible

Wet amount/smear: _____

GROSS INTERNAL EXAMINATION

Adipose Tissue:
( ) Normal ( ) Excessive ( ) Reduced ( ) Petechial Haemorrhagic
( ) Colour _____ ( ) Cysts

Liver: ( ) Normal ( ) Enlarge ( ) Reduced Colour: ( ) Pale
( ) Mottled
( ) Other _____ Texture: _____
( ) Lesions: ( ) Single ( ) Multiple ( ) Tumour
( ) Necrotic ( ) Haemorrhagic ( ) Cyst (parasite) ( ) Cyst(fluid)

Spleen:

( ) Normal ( ) Enlarged ( ) Reduced ( ) Raspberry surface
( ) Cyst(parasite) ( ) Cyst (fluid) ( ) Colour _____

Stained smear: _____

Intestines:

( ) Normal ( ) Distended (fluid) ( ) Distended (mucoid)
( ) Flaccid ( ) Haemorrhagic ( ) Cysts(parasite)
( )Tumour

Kidney, Posterior:

( ) Normal ( ) Enlarge ( ) Lesions ( ) Single
( ) Multiple ( ) Gritty, white ( ) Cyst (parasite) ( ) Cyst(fluid)
( ) Tumour

Stained smear: _____

OTHER: _____