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PHASE II - FINAL REPORT

FRESHWATER ECOLOGY

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PHASE II - FINAL REPORT - FRESHWATER ECOLOGY BIOENVIRONMENTAL AND RADIOLOGICAL SAFETY -- FEASIBILITY STUDIES - ATLANTIC-PACIFIC INTEROCEANIC CANAL.

W. L. Templeton, J. M. Dean, D. G. Watson and L. A. Rancitelli

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RESEARCH REPORT

ON

BIOENVIRONMENTAL AND RADIOLOGICAL-SAFETY FEASIBILITY STUDIES

ATLANTIC-PACIFIC INTEROCEANIC CANAL

PHASE II - FINAL REPORT

FRESHWATER ECOLOGY

BY

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SECTION I

INTRODUCTION

The purpose of this program is to conduct studies in the freshwater environment to acquire data needed to evaluate and predict the potential radiation hazards to human populations in the defined regions of proposed nuclear excavations in the Republics of Panama and Colombia.

The relevant published and background data to the Phase II studies have already been reported and published as IOCS Memorandum BMI-8, BMI-850.01

The results of the field surveys conducted in Phase II are presented in this report. Specifically, the data describes the elemental composition of the major components of the ecosystem, and reports the calculated stable element concentration factors for the major food organisms. This data provides baseline values from which predictions can be made of the potential maximum radionuclide intake by populations using this resource.

The relevant literature has been surveyed and comparative data compiled and discussed.

The predictions of maximum concentrations and specific activity ratios of the potentially critical radionuclides have not been calculated since the required input from other programs, particularly Hydrology and Terrestrial Ecology is not yet available.

The limited time period allowed for this study has not allowed detailed synthesis of all the collected data, particularly the bio-geochemical aspects, but it is intended that this will be presented at the Symposium in September 1968 and also published in the literature.

The detailed sample data is presented in a separate Appendix.

PHYSICAL CHARACTERISTICS OF RIVERS

The nature and composition of the channel and shores of rivers in Panama and Colombia are as varied as the terrain through which they flow. It would appear that gradient and substrate are the major factors in determining the composition of the river bed. In areas of high elevation and steep gradient, rock and gravel substrata constitute the river channel, while in areas of reduced velocity, sand and mud are deposited. The latter usually occuring only in wide deep regions, such as pools. Finer sediments are normally transported to lower regions while light organic materials generally do not settle out until the river reaches near base level. Thus, a gradation in the nature of the bed and shores exists from the fast water, rocky bed zone to the slow water, mud bed region. Erosion, as it occurs, is primarily channel erosion. There is very little direct sheet runoff into the streams.

Upper River Course

High elevation rivers and streams are typified by steep gradients resulting in high velocities, with occasional pools being formed. In the fast stretches the channel and often the shores are strewn with boulders and rubble of various sizes. Where a pool interrupts the course, the bottom may contain light deposits of sands and organic detritus. This is typical of the Rio Chucunaque at Uala[2], the upper Rio Salaqui[59], Rio Nercua[56], and Rio Salado[58].

Middle River Course

The middle river course typically exhibits a more inclined gradient and greater velocity than is found in the lower course. In this middle zone, the bottom is usually characterized by coarser material, gravel, and some cobblestones with mud and lighter sediments being found only in pools or sidewaters. This would be characteristic of the sampling stations at the Rio Curiche(51), the Rio Pirre(13), Rio Truando at Terresita(54), Upper Rio Truando(53), Rio Narka(27), and Rio Sabanas(21).

Lower Stream Course

As a river nears its base level and approaches its mouth, the bottom typically is composed of loose muds, silt, and organic detritus. Because the river flows in a broad flood plain of low relief, the shores may be poorly defined and be bordered by swamps or, in the case of the lower Chucunaque, have numerous oxbows. Rivers typical of this formation are the Tuira(12) and Chucunaque at El Real(7), the Atrato at Rio Sucio(63) and Sautata(64). The definition or impressions just described of stream bottoms and shores are, very generalized, and there is a continuum from one to another. Thus, rivers such as the Nercua(56), Sabanas(21) and upper Truando(53) are, perhaps, intermediate between lower and middle stream course definition. Local climatic conditions in terms of humidity and rainfall, soil types, land elevations, and configuration, all serve to greatly modify the river from source to mouth.

DESCRIPTION OF SAMPLING SITES

The following describes the sampling sites where comparable samples were obtained during the wet and dry seasons.

Station 2 - Rio Chucunaque At Uala.

The river at Uala is in its upper region. In front of the village the river divided to form an island. The smaller channel being nearer the village and cutting through prominent layers of limestone. Sampling was conducted in the main channel of the river just above the confluence with the smaller channel. This avoided problems of contamination, as the smaller channel was heavily utilized for bathing, laundry, and waste disposal. The river was about 180 feet wide at the point of sampling and shallow enough so that in most places one could walk across. The river bottom consisted of sand, gravel and cobblestones. There was essentially a 100% canopy from Uala to its source, however, below Uala, the canopy was intermittent. There was very little periphyton in the river, and no striking evidence of aquatic macroinvertebrates, with the exception of some snails. Fishing was done by rotenone in a pool, and was not particularly successful; however, it was known that the Indians had used dynamite to fish these pools in the recent past.

Station 6 - Rio Chucunaque below Yaviza and above El Real.

At this point, the Chucunaque was about 450 feet wide. It was in the very lower reaches and, as such, a highly meandering stream with a large suspended sloids load. The banks of the river were very abrupt with large amounts of rooted vegetation being seen where the banks were undercut. The height above the water line varied as the tide range was considerable. Water samples were taken from mid-channel while the sediment samples were from along or off of a mud bar. In the area of collection, the bottom consisted of fine mud, with no evidence of gravel. The river was very open at this point and quite wide. No periphyton was observed, probably due to the lack of light transmission resulting from a large suspended solids load. Fishing was done at this station using both hook and line and spears.

Station 12 - Rio Tuira above El Real.

The river was approximately 450 feet wide and appeared very similar to the Rio Chucunaque above El Real. The water samples were taken midstream and the bottom samples taken from the edge of a mud bar in the river proper. There was no canopy at this station.

Station 13 - Rio Pirre above El Real.

The Rio Pirre acts as the water supply for the village of El Real. At the station, which was above the intake for the water supply, the river was about 35 feet wide. The river had a gravel and cobblestone bottom, flowed fairly rapidly, was very shallow under low flow conditions, and appeared very clear. A canopy of 100% encompassed the river in most areas. The fishing was done with rotenone and was fairly successful. The Indians fish with spears hook and line and did very well. Macroinvertebrates and periphyton were observed infrequently.

Station 21 - Rio Sabanas.

The station was based at the Sabanas Hydro Station. At low flow, the river was about 20 feet wide, and flowed slowly through a series of pools. The banks were quite high, and there was a very complete canopy over most of the river. The bottom was sand, gravel and mud. There was some periphyton present on the rocks during low flow, however, during high flow, there was a very high load of suspended solids with no periphyton being visible.

Station 22 - Rio Congo.

The Rio Congo has its source in a ridge of mountains that are unexplored even by the large Choco Indian population of the area. Sampling was conducted just above the confluence with the Rio Dovoca. The Congo during periods of low flow, was approximately 35 feet wide and very shallow. The Congo cut through limestone strata with banks being about 10 feet high. The bottom consisted of rock, sand, gravel and shelves of limestone. Numerous pools and falls existed in the area of sampling. It was noted that the river fluctuated quite rapidly in this area. A canopy of approximately 30% existed over the river. In addition to excellent fishing in the pools, large numbers of crustaceans, snails and encrusting algae were found.

Station 25 - Rio Cuadi.

The Rio Cuadi was sampled approximately a quarter-mile from the Sasardi Hydro Station. At that point, the river was about 30 feet wide and formed a series of pools. The bottom was sand and gravel, and there was a 100% canopy. The characteristics of this station are very similar to those of stations 27, the Rio Narka, and Station 26, the Rio Aligandi. Fish collection was accomplished by use of both rotenone and Fintrol. Differential toxicity was noticed, which resulted in a successful collection of all fish in the area. There was very little periphyton in the river, probably due to the canopy.

Station 26 - Rio Aligandi.

The characteristics of this station have been described for 25 and 27. The samples were obtained above the site at which laundry, bathing, and water collecting were done by the women of Aligandi.

Station 27 - Rio Narka.

The Rio Narka was about 30 to 40 feet wide and flowing at the point of sampling. This being a 30 minute hike from the beach. The river had a bottom that was typical of short rivers of the Atlantic drainage consisting of sand, gravel, and mud. Fishing was done with rotenone and was very successful in pools. There were small amounts of periphyton on the rocks in the shallower water. The canopy was about 50% in the area of the station. This appears to be a typical covering for streams of this drainage.

Station 28 - Rio Sablo.

The Rio Sablo was sampled above the village of Cañazas and the confluence of the Sablo and Rio Cañazas. The river was about 15 to 20 feet wide, extremely clear, and had the classical characteristics of a river in its upper reaches. The gravel and cobblestone bottom was covered with a shallow layer of water, which flowed rapidly over and between large boulders. Fishing was accomplished in a pool, and was very successful. There was very little silt or periphyton present at this site.

Station 29 - Rio Grande.

The Rio Grande was sampled above the bridge of the Trans-American Highway where it crosses the river northwest of Penonome. The river at this point was about 150 yards wide and very shallow in both the wet and dry seasons. Sampling was done from a large gravel bar, which was located immediately above a deeper area of the river. In the deeper water extensive swimming, bathing, and laundry activity took place. This station was in the middle reaches of the river, consequently having a sand and gravel bottom. There was substantial utilization of the land on either side of the low banked river for agricultural purposes. No fishing was attempted at the station.

Station 30 - Rio Santa Maria.

The Rio Santa Maria was sampled beneath the bridge just before entering the village of Divisa. The river was extremely large estimated to have one of the highest flows in Panama. At the point of sampling, it was about 150 yeards wide and quite deep (could not be forded). The floor of the bridge was about 30 feet above the river level during periods of low flow, but during flood stages, the water flows over the floor of the bridge. The water samples were obtained from the right bank of the river. The bottom of the channel consisted of sand and gravel with some cobblestones,with very little periphyton being observed on the rocks. The water was used for irrigation purposes in pastures and for sugar cane, and other agricultural products.

Station 31 - Rio La Villa.

Sampling was conducted from a bar extending from the right-hand bank just above the bridge crossing the river between Chitre and Los Santos. The river was quite deep and had a sand and gravel bottom. The banks were about 12 feet high and quite steep. The river was used for irrigation purposes and as a drinking water supply.

Station 51 - Rio Curiche.

Samples were taken above the confluence of the Rio Curiche and its tributary, the Quebrada La Rita. At this point, the Rio Curiche was about 50 to 60 feet wide, had a sand and gravel bottom, and was flowing at a fairly good rate. The river had about an 80% canopy, and steep banks. No periphyton was observed. Fishing was successful in the pools with rotenone, however, the area had been fished by Indians using dynamite in the past. Sediment samples were taken at the downstream end of a gravel bar.

Station 52 - Rio Jurado.

Samples of the Rio Jurado were obtained in its upper regions and at the confluence of two tributaries. At this point, the river is quite young, having a bottom of large boulders, cobblestones, sand, and gravel. No periphyton was observed on the rocks at this station. The banks were very steep, and a canopy of essentially 100% existed over the river. The river was successfully fished with rotenone. There were no Indian population to speak of in the area.

Station 53 - Upper Truando above its confluence with the Rio Nurcua.

The station was located by the OICS Hydro Station 12 miles above the confluence of the Truando and Nercua. The river has maintained base level, assuming meandering characteristics in the area of the sampling station. The river bottom was composed of sand, gravel, and mud, with no periphyton being observed. Sediment samples were taken from the lower end of a gravel bar upon which the helicopter landed. No homes or Indian families were observed along the river.

Station 54 - Rio Truando at Teresita.

In the area of sampling, the river Truando assumes a lesser gradient resulting in numerous meanders until it joins the Salaqui and Atrato. The station was located just above base camp and below the canyon of the Truando where numerous falls and rapids exist. The river was 80 to 100 feet in width. The bottom was composed of sand, gravel, and mud with steep banks existing on both sides. The canopy had been removed at the station, however, just upstream a canopy of 80% existed. Fishing, done in a tributary of the Truando with rotenone, was quite successful. Sediment samples were taken from the bank of the river.

Station 56 - Rio Neurcua near Hydro 9.

In its upper reaches, the Nercua was about 40 feet wide and flowed rapidly over a sand and gravel bottom, whereas by Hydro 13, downstream of station 56, the Neurcua assumed the characteristics of a meandering river as its gradient became much less. The canopy near Hydro 9 was essentially 100%. Fishing was successful in a tributary of the river with rotenone. Sediment samples were obtained at the lower end of the bar upon which the helicopter landed.

Station 58 - Rio Salado.

This station was sampled by hiking about 45 minutes from the Teresita base camp. At that point, the Salado was 30 to 40 feet wide, with a sand, gravel and cobblestone bottom. The river had essentially 100% canopy with little periphyton or macroinvertebrates being seen. The fishing was done with rotenone in the pools and was extremely successful. Sediments were taken from the bottom of the river below a pool.

Station 59 - Rio Salaqui.

Station 59 was above Hydro 4, where the river was 80 to 100 feet wide and in its upper reaches. It had a high velocity and was too deep to wade across, even in the dry season. The bottom was sand and gravel, with some cobblestone and limestone shelves. The banks were very steep and covered with a 100% canopy. Little periphyton was observed along the edges of the river. In a nearby tributary, fishing was successful using rotenone in the pools. Sediment samples were obtained at the lower end of a sand and gravel bar.

Station 60 - Rio Salaqui.

Station 60 was near Hydro 11. Samples were taken on a gravel bar in the center of the river. The river being about 150-180 feet wide, very swift and flowing through a canyon of limestone walls. There was a 20% canopy over the river. The bottom was sand and gravel consisting of a great deal of quartz. Material which is ordinarily considered to be gravel, is extremely white. No fishing was attempted at this station.

Station 61 - Rio Salaqui.

This station was located at the lower reaches of the Rio Salaqui. The river was about 150 yards wide, quite deep, with steep mud banks and bottom. A meandering course had been assumed in the area of the station. Water samples were taken immediately adjacent to Hydro 12, and no fishing was attempted. The land adjacent to the river was under cultivation during the periods of sampling.

Station 62 - Rio Atrato.

Samples were taken from the bank immediately adjoining Hydro 16. The station was located above the town of Rio Sucio, and the confluence of the Atrato with Rio Truando and Rio Salaqui. The river is about 600 yards wide at the station.

Station 63 - Rio Atrato below Rio Sucio.

The Atrato below Rio Sucio lies downstream from the confluence of the Salaqui and Truando. The river was very meandering with numerous oxbows in the process of formation. Water samples were obtained by taking a boat to mid-channel in an area where the river was approximately 600 yards wide. Sediment samples were taken from a mud bar extending into the river. Fishing was done by hook and line and was very successful in the dry season while not as successful in the wet.

Station 64 - Rio Strato at Sautata.

The characteristics of the Atrato at Sautata were very similar to those at Rio Sucio with the exception that the river was about 800 yards wide. The course of the river was completely exposed with no canopy. Fishing was done by hook and line.

Station 65 - Sautata swamp.

Samples were taken from the water adjacent to the railroad track leading to the river from Sautata. The water resembled that found in the Cienegas, as it had a deep tea color.

Station 66 - Cienega de Perancho.

Surface samples were taken from the center of the Cienega. The color of the water was similar to that of the Sautata swamp.

Station 67 - Rio Perancho.

This station was located below the confluence of the Perancho with the Rio Cacarica. The river was about 60 feet wide and about 8 feet deep, with a mud and sand bottom. No fishing was attempted, although fish were observed in the water.

Station 68 - Rio Cuti.

The Rio Cuti was sampled after a 30-minute hike above the village of Santa Maria de Nueve. The swiftly flowing river covered by a 100% canopy was about 20 feet wide and three feet deep. It had a clay and sand bottom. Fishing was done by net with moderate success. It was later learned that natives had fished the area using dynamite.

SAMPLING PROCEDURES

Sampling of stations on Routes 17 and 25 was carried out during both the Dry and Wet seasons. The sampling periods were (A) Dry I - 2/14/67 through 4/12/67, (B) Wet I - 8/22/67 through 9/15/67 and (C) Dry II - 1/31/68 through 2/20/68.

For the sampling period Dry I, the water was collected and stored in polyethylene containers and shipped to the laboratory without treatment in the field. During Wet I the collecting procedure was modified as follows: three water samples were collected in polyethylene containers and transported to the base camp. As soon as possible a measured volume of water of the first sample was filtered through an 0.45 μ Millipore filter (PVC Millipore Filter Holder - Catalog No. YY-4014200, Filter Model No. WHWP 14520). The filtrate was collected in a clean polyethylene bottle, labeled and stored for chemical analysis. The filter was allowed to dry for 15 to 20 minutes on a paper towel before being labeled and sealed in a plastic bag. The second sample was not treated before being labeled and stored.

At the same time as the filtration was taking place, a sample of 40 ml of water from the third sample, was centrifuged in a polyethylene tube at 1,000 X G for one hour for activation analysis. The supernatant fraction was removed with a polyethylene pipette and placed in a polyethylene bottle that had been rinsed with double-distilled nitric acid and 1.0 ml of double-distilled nitric acid was added to the sample. The precipitate was considered to be the

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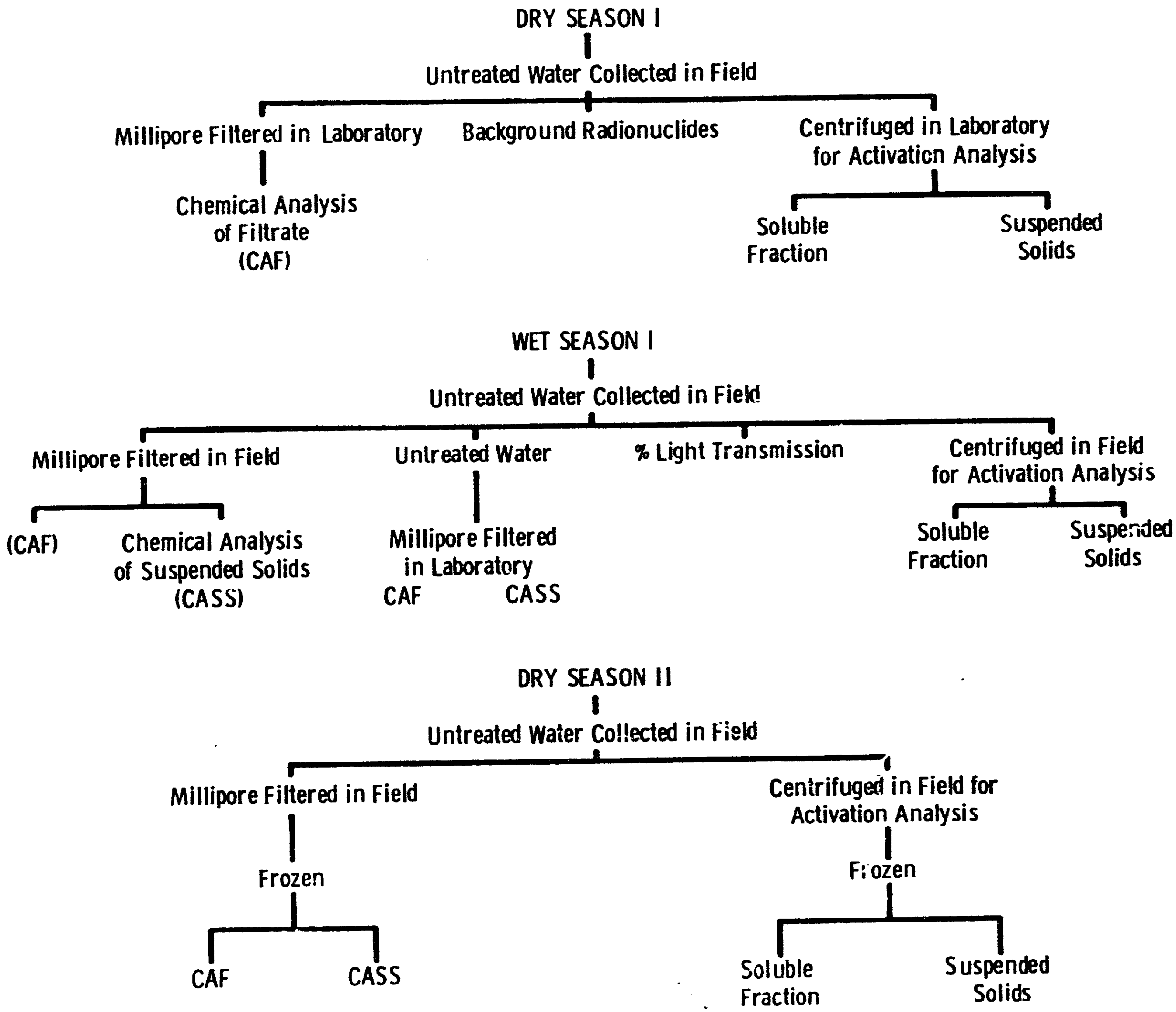

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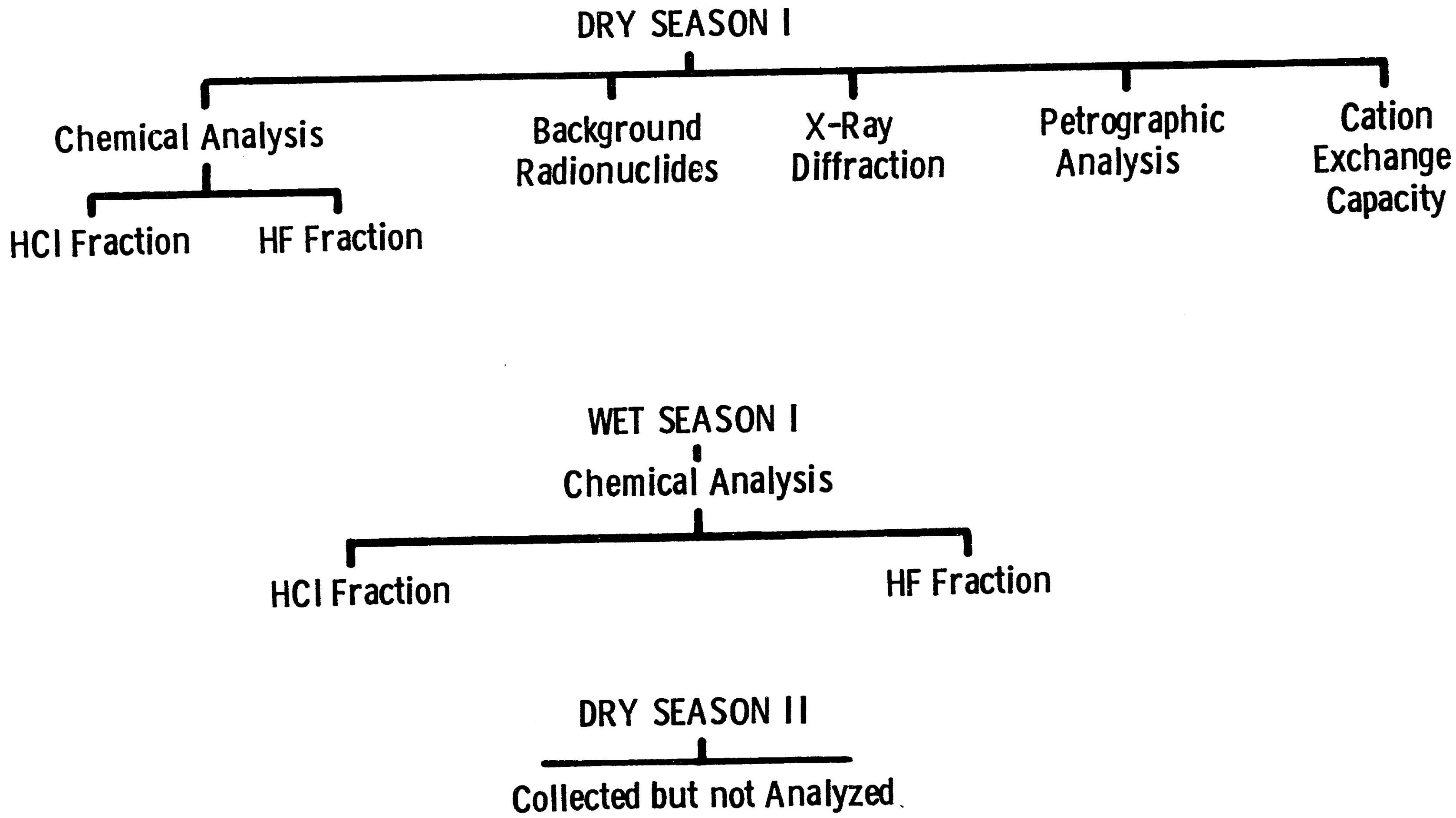
River Sediments



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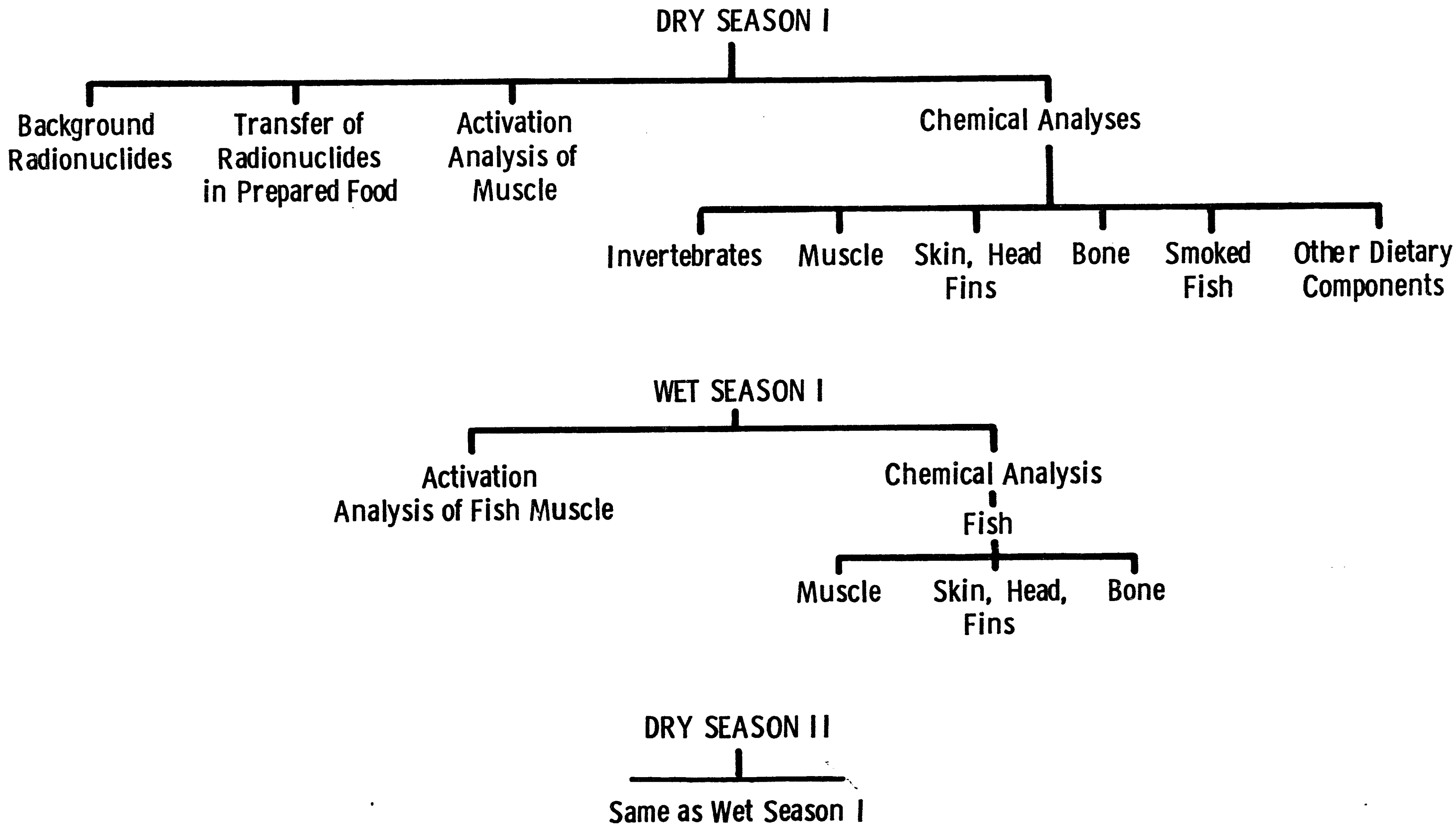
Tissue



suspended solid and was stored for activation analysis. This water sample contacted only polyethylene to reduce adsorption problems and contamination. (Fig. 2).

At the sampling site, several hundred grams of river sediment were collected and stored in a polyethylene container.(Fig.3).

For the Dry II sampling period, all collections were made at the respective stations (Figure 1 , Table 1), and were handled in the same manner as Wet I, except that immediately after Millipore filtration and centrifugation, the samples were frozen. All samples were shipped air freight to the laboratory, and remained in a frozen state until analyzed.(Fig. 4).

All samples were collected and processed in as short a time period as possible. In Wet I and Dry II three hours was the maximum time period between collection, filtration and centrifugation.

Fish were collected for analysis by poisoning a section of the river with the fish toxicant, "Rotenone". If the river was too large at the station where water and sediments were collected, we sampled a nearby tributary. Fish were collected after application of the rotenone as they suffered respiratory embarrassment.

Fresh, dried and smoked fish were also purchased from the natives. When available samples of crustaceans, snails, and other aquatic organisms utilized as diet items by the people of the region were collected. Fish to be used for chemical and activation analysis were separated according to family and frozen as soon as possible in double polyethylene bags, generally within three hours. Sub-samples of these and special collections made for taxonomic and biogeographic studies were fixed in formaldehyde.

During Dry I, plankton was collected in a standard plankton net, fixed in a small plastic bag or vial with formalin, and sent to the laboratory for storage. Sample size was usually too small for reliable analysis.

TABLE I. APPROXIMATE LATITUDE AND LONGITUDE OF STATIONS IN PANAMA

Station Number	Latitude	Longitude
1	9° 02'	78° 02'
2	9 00	78 01
3	8 51	77 59
4	8 47	78 00
5	8 14	77 41
6	8 12	77 44
7	8 11	77 44
8	8 54	77 53
9	8 41	77 41
10	8 17	77 38
11	8 14	77 36
12	8 11	77 41
13	8 07	77 42
14	8 07	77 45
15	8 10	77 34
16	7 59	77 51
17	8 11	78 00
18	8 19	78 05
19	8 17	78 07
20	7 52	78 05
21	8 45	78 07
22	8 44	78 24
23	8 40	78 22
24	8 50	77 37
25	9 00	77 45
26	9 14	78 03
27	9 15	78 04
28	9 06	78 07
29 Azuero Peninsula	8 25	80 30
30 " "	8 06	80 40
31 " "	7 50	80 25
32 " "	7 22	80 28
33	8 28	78 09
34	No Station	No Station
35	7 28	77 57

TABLE I. APPROXIMATE LATITUDE AND LONGITUDE FOR STATIONS IN COLOMBIA

Station Number	Latitude		Longitude	
51	7°	00'	77°	36'
52	7	27	77	45
53	7	01	77	28
54	7	08	77	25
55	No Station		No Station	
56	7	11	77	33
57	7	06	77	32
58	7	08	77	27
59	7	37	77	41
60	7	33	77	33
61	7	26	77	21
62	7	23	77	06
63	7	28	77	07
64	7	49	77	08
65	7	51	77	08
66	7	42	77	11
67	7	45	77	09
68	8	12	77	07
69	8	34	77	18
70	7	04	77	34
71	7	10	77	42
72	7	25	77	22

ANALYTICAL PROCEDURES

(a) Elemental analysis by chemical-physical methods

Samples of water, suspended solids sediments and biological tissue were analyzed for Na, K, Ca, Mg, Sr, P, Fe, Mn, Cr, Zn and Cu.

Field-filtered water samples were refiltered through a 0.45 (Table 2) micron millipore filter prior to analysis. The filtrate was acidified with nitric acid to prevent further precipitation of elements. The filters with residue were also analyzed. Blank filters were analyzed and the results applied as a correction factor.

Samples of biological tissue were dried at 150° C and muffled at not more than 500° C. The ash was digested in hot 6M hydrochloric acid and diluted 10-fold prior to analysis.

Sediment samples were dried (100°C), weighed, then digested for 7 hours in 6M hydrochloric acid at 80-90°. The mixture was filtered and the filtrate was analyzed as "HCL digest". The residue was digested 18 hours in 8 M HF at 80-90° then taken to dryness. The residue from the HF treatment was digested with hot 6 M hydrochloric acid, then filtered. The filtrate was analyzed as "HF digest" and the residual solids were discarded.

The methods employed were as follows:

METHODS

Ion	Method[a]	Sample Treatment	Ref.[b]
Na	(1)	None	1
K	(1)	None	1
Ca	(3)	1% La present	2
Mg	(3)	1% La present	2
Sr	(3)	1% La present	2
		(water samples were concentrated by coprecipitation with $Ca_3(PO_4)_2$)	
PO_4	(2)	Heteropoly blue method, antimoney ascorbic acid modification	3
Fe		Water samples were concentrated by coprecipitation with $Cd(OH)_2$ from a reducing solution	2
Mn	(3)		2
Cr			2
Zn	(3)	Water samples were pre-extracted as pyrrolidine dithiocarbamate complexes into methyl isobutyl ketone	2
Cu			2

Method[a]

(1) Flame emission spectroscopy (FES) was done with a Beckman DU spectrophotometer equipped with a Beckman flame photometer and spectrum scanning accessories.

(2) Colorimetry was done with a Beckman DU spectrophotometer and 10 cm cuvettes.

(3) Atomic absorption spectrophotometry (AA) was done with a Perkin Elmer Model 303 spectrophotometer equipped with a Boling Burner and digital read-out.

b) CHN Analysis of Biological Tissue

Biological tissues were analyzed for carbon, hydrogen and nitrogen with an F and M Model 18C CHN analyzer. An organic sample was weighed and place in a combustion furnace that was packed with cupric oxide and operated at ~1100°C. Combustion took place in a static helium atmosphere and was supported by the oxygen furnished by a mixture of chromic and tungstic oxide that was in intimate contact with the sample. After combustion was complete (~20 seconds), the products of combustion were swept over the hot cupric oxide to insure their conversion to carbon dioxide and water. The nitrogen and oxides of nitrogen (formed during the combustion of organic nitro compounds) along with the carbon dioxide and water now passed through a furnace packed with copper metal. The copper metal at 500°C selectively reduced any oxides of nitrogen present to molecular nitrogen. The combustion products then passed into a gas chromatograph where they were separated and analyzed using a thermal conductivity detector. The electrobalance was used in such a way as to attenuate the recorder response proportionally to the sample weight; therefore, two samples of the same material will give identical instrument responses. The instrument's response to CO_2, H_2O and N_2 was determined using a primary standard (cyclohexanone, 2, 4,-dinitrophenylhydrazone) and these factors were used to calculate the CHN content of unknown samples. This analysis technique was very rapid and exhibited the same precision and accuracy as the classical combustion and weighing technique. However, sampling problems were more acute using this instrumental technique since the linear response region of the thermal conductivity detector dictates a sample size of 0.5-0.7 mg.

The main difficulty with the fish samples was their heterogeneity. Duplicate analysis on three samples were tried but were not reproducible to the $\pm$ 0.3% limits traditionally imposed on CHN analysis. Standard runs showed excellent agreement, however, (C $\pm$ 0.3%; N $\pm$ 0.2 - 0.3%; H $\pm$ 0.1 - 0.2%).

c) Sediment characterization

Moisture - Moisture content was determined by measurement of loss of weight from the sample as received when dried to 110°C.

Grain Size Analyses - Wet and dry sieve.

Cation Exchange Capacity - The cation exchange capacity was determined by an isotopic dilution method by use of ^{85}Sr in a 0.2 N $Sr(NO_3)_2$ solution. Two grams of sediment were brought to equilibrium with the strontium solution. Equivalent volume counting was used to determine the amount adsorbed.

Ignition Weight Loss - Determined by weight loss from 110°C to a constant weight at ignition temperature in a platinum crucible over an open burner flame.

Elemental Analyses - The elements were determined by X-ray emission spectrography. Recovery was based on the sample at 110°C.

Mineralogical Analyses - Minerals and rocks were identified by X-ray diffraction techniques, supplemented by visual examination under a binocular microscope. Magnetic minerals were segregated using a magnetic separator.

d) Neutron Activation Analysis of Samples

Water

Two subsamples were removed from each water sample supplied for analysis; a water sample containing its particulate suspended matter, and a second sample in which the particulate matter had been largely removed by centrifugating. The water sample was shaken thoroughly and a 100 microliter protion was transferred to and sealed in a clean 3 ml I.D. X 5 cm long quartz ampoule. A sample of water which was free of particulate matter was obtained by centrifuging an aliquot of the water in a polyethylene tube for an hour at 1000 X G. Calculations indicated that particles larger than 1 micron and with a density greater than 3 would be effectively removed. A 100 microliter portion of this water was sealed in a quartz ampoule. All quartz ampoules employed for neutron activation analysis were first refluxed in nitric acid for several days to remove leachable surface impurities. A series of flux monitors were prepared in similar containers by pipetting known amounts (about 10^{-8} g/ml) of dilute acid solution of the elements of interest into sealed quartz ampoules.

The water samples and standards were simultaneously irradiated in a Hanford production reactor to an integral thermal neutron exposure of about 4×10^{19} n/cm^2. The portion of the reactor employed for these irradiations is characterized by an extremely flat, highly thermalized neutron flux. After permitting the samples to decay several days, the ampoules were washed several times in nitric acid to ensure a minimum transfer of reactor contamination from the surface of the ampoule to the sample. The ampoules were then carefully broken open and a 50 microliter portion of the sample was dried on a 1 inch steel dish. The dish was lacquered and wrapped in several layers of Saran Wrap. The standard flux monitors were handled in an identical manner.

The samples were counted for 10 minuted with an anticoincidence shielded gamma-gamma coincidence multidimensional analyzer [(4)] to determine the ^{24}Na activity. The samples were then permitted to decay several weeks before counting them for 1000 minutes with the multidimensional analyzer to determine the activities of ^{46}Sc, ^{60}Co, ^{65}Zn, ^{110m}Ag, ^{124}Sb, ^{134}Cs and $(Ba\text{-}La)^{140}$ from U-fission. The activity of the isotope of interest in the sample, after a suitable decay correction, was compared with the specific activity of the standard to obtain the elemental content.

The large number of samples, the several experimental problems, and the nature of this study made it impractical to analyze duplicate samples; however, the precision of this method was estimated by a replicate analysis of redistilled water. The results of the distilled water analysis are presented in Table 3 . An estimate of the error associated with the determination of each element is presented in Table 6. These estimates are based for the most part, on counting statistics which represents the major error due to the small amounts of materials present. Other sources of error such as self shielding and secondary reactions are considered negligible.

A source of error not considered in the early samples was the loss of soluble elements from the solution after collection. This was recognized as a large effect during the course of these experiments. Two of the river samples were centrifuged, sampled for activation analysis and the remainder of the clear river water was placed in a polyethylene bottle. A second set of samples was removed from the bottle at a later date for analysis. From the results of this experiment which are tabulated in Table 4, it is evident that a large portion of the soluble content had been lost. This effect could also reflect a contamination of the first set of samples, however, it was thought that this was not the case. Freshly centrifuged river samples develop a cloudy appearance after standing several weeks, and this is characteristic of iron colloid development. In addition to adsorption on the polyethylene, it is possible the solutions became more basic through loss of CO_2 causing the iron in the sample to precipitate as the hydroxide with an accompanying scavenging effect on all other trace elements. At present this is merely conjecture to explain the observed loss of trace quantities of transition metals with time. Dry II water samples were frozen immediately after collection to ensure a status quo condition until sampling for activation analysis could be performed. The sodium contents of thirteen samples agreed within 10% of the results obtained by atomic absorption spectroscropy.

Biological Samples

In the case of biological samples, the method involves the following. Representative samples of muscle tissue weighing several grams were dissected in a manner shown to introduce negligible contamination. The tissue was placed in specially cleaned polyethylene containers, freeze dried, and irradiated with a thermal neutron exposure of about $10^{17} n/cm^2$ together with aqueous solutions containing known amounts of elements of interest. After a decay interval of several days the sample was removed from the irradiation capsule, crushed, mixed with a hot 2% augar solution and poured into a ½" x 2" ring to achieve a standard counting geometry. The sample and standards were then counted for 10 minutes with a 20 cc. coaxial Ge(Li) detector to determine the induced activities of ^{24}Na, ^{42}K, ^{82}Br. A decay interval of about 20 days was then allowed to ensure the complete removal of ^{82}Br. At this time, the sample was again counted with a 20 cc. Ge(Li) diode for 1000 minutes to determine the activities of ^{51}Cr, ^{59}Fe, ^{60}Co, ^{65}Zn, ^{75}Se, ^{86}Rb, ^{134}Cs and ^{203}Hg. Finally the sample was counted for 1000 minutes with an anticoicidence shielded gamma-gamma coincidence multichannel analyzer, to determine the activity of ^{46}Sc, ^{60}Co, ^{65}Zn, ^{110m}Ag, ^{124}Sb, and ^{134}Cs. The activity of each isotope, after applying a suitable decay correction to the sample, was compared with the specific activity of standard irradiated along with the sample to determine the quantity of each element present. Three elements, cobalt, cesium and zinc, were determined by both the gamma-gamma coincidence method of analysis and with the solid state detector. The excellent agreement (10%) of results obtained by the two instrumental methods confirmed the reliability of the two methods of gamma-ray analysis.

Due to the large number of samples involved and the nature of this survey, it was not feasible to analyze duplicate samples. However, the precision (5-10%) of this method has been demonstrated in the analysis of replicate samples of cellulose tissue. An estimate of the error associated with the determination of each element is presented in Table 25 along with the results. These estimates are based upon counting statistics, self-shielding errors, contamination, volatile loss during processing, and side reactions leading to the same isotope. In all but one case this latter effect is negligible. In addition to neutron capture by ^{45}Sc. Hence, the scandium content reported should be considered an upper limit to the actual value.

e) Low level gamma-ray spectrometry

Samples of water, bottom sediments and biological tissues were analyzed for natural and weapon test fallout radionuclides.

Water samples were processed through a high volume sampler and radioactivities determined[6]. The minimum detectable activities are presented in Table 28.

f) Radiochemical Analysis for ^{90}Sr

Water

Strontium carrier was added to a measured volume of each water sample, the sample was acidified with nitric acid and evaporated to about one liter. The solution pH was adjusted to about 10 with 12N sodium hydroxide and sodium carbonate was added to precipitate strontium carbonate. The strontium carbonate precipitate was dissolved in nitric acid and strontium was precipitated as the oxalate at pH 5.

The oxalate precipitate was dissolved in nitric acid and strontium nitrate was precipitated by addition of fuming nitric acid. Barium was removed by precipitation as the chromate at pH 5. Strontium carbonate was precipitated and mounted on a tared stainless steel dish for beta counting. Fourteen days were allowed for yttrium ingrowth and yttrium was separated by three successive precipitations of yttrium hydroxide in dilute ammonium hydroxide solution. Finally yttrium was precipitated as the oxalate; mounted on a tared dish, flamed to the oxide, weighed, and beta counted.

Biological Tissue

The samples were separated into four fractions of approximately 1000 grams each. Strontium carrier was added and they were then covered with nitric acid and allowed to digest under a heat lamp until they were reduced to a dry solid. The samples were then ashed in a muffle furance at 540° C for 48 hours and wet ashed with fuming nitric and 30% hydrogen peroxide to remove any remaining carbon. The ashed salts were transferred to centrifuge cones with fuming nitric acid, centrifuged and the supernatant fraction was discarded. The salts were then washed three times with 14N nitric acid. The remaining salts were leached with three each alternating 5 ml Hydrochloric and nitric acid fractions. The resulting supernate was adjusted to pH 5 with ammonium hydroxide and strontium was precipitated as the oxalate.

The oxalate precipitate was dissolved in nitric acid and strontium nitrate was precipitated by addition of fuming nitric acid.

From this point the analysis parallels that of the water samples following the oxalate precipitation of strontium.

SUMMARY OF ANALYSES

● H_2O AND SUSPENDED SOLIDS

CHEMICAL ANALYSIS	Na	K	Ca	Mg	Fe	Mn	Cr	Cu	Zn	Sr					P					
ACTIVATION ANALYSIS	Na								Zn		Cs	Co	Sc	Ag						Sb
BACKGROUND RADIONUCLIDES	^{22}Na	^{40}K								^{90}Sr	^{134}Cs ^{137}Cs	^{60}Co				^{108}Ru	^{144}Ce	^{208}Ti	^{214}Bi	

● TISSUE

CHEMICAL ANALYSIS	Na	K	Ca	Mg	Fe	Mn	Cr	Cu	Zn	Sr									P	%C, %H, %N				
ACTIVATION ANALYSIS	Na	K			Fe		Cr		Zn		Rb	Cs	Br	Se	Co	Sc	Ag	Hg						Sb
BACKGROUND RADIONUCLIDES	^{22}Na	^{40}K								^{90}Sr		^{134}Cs ^{137}Cs			^{60}Co					^{108}Ru	^{144}Ce	^{208}Ti	^{214}Bi	

● SEDIMENTS

CHEMICAL ANALYSIS	Na	K	Ca	Mg	Fe	Mn	Cr	Cu	Zn	Sr		SiO_2	Al_2O_3
X-RAY DIFFRACTION		K_2O	CaO	MgO	Fe_2O_3						TiO_2	SiO_2	Al_2O_3

TABLE 3 . CONCENTRATIONS OF SEVERAL TRACE ELEMENTS IN DISTILLED WATER

(nanograms/ml)

Elements	Sample 1	Sample 2	Sample 3	Sample 4	Average ± 0
Sb	0.054	0.050	0.046	0.050	0.050 ± 0.00
Co	0.04	0.02	0.06	0.02	0.04 ± 0.02
Sc	0.0005	0.0015	0.0004	0.0006	0.009 ± 0.00
Cs	<0.006	<0.006	<0.006	<0.006	<0.006
Zn	2.9	3.3	3.2	2.5	3.0 ± 0.2

TABLE 4 . TRACE ELEMENT LOSS OF A RIVER SAMPLE ALLOWED TO STAND ONE MONTH

	Rio Teresita		Rio Sabanas	
Element (ppb)	2/20/67	3/15/67	2/20/67	3/15/67
Sb	0.01	0.01	0.20	0.08
Sc	0.02	0.003	0.02	0.003
Co	0.16	0.04	0.12	0.04
Cs	0.06	0.01	0.04	0.01
Zn	17.8	17.2	10.5	4.6

REFERENCES

(1) Flame Photometry, Chapter 12, John A. Dean, McGraw-Hill Co., New York, 1960.

(2) Analytical Methods for Atomic Absorption Spectrophotometry Perkin Elmer, January 1964.

(3) Phosphate Determinations in Water, J. Murphy and J. P. Riley, Department of Oceanography, Liverpool, Great Britian, Anal. Chimica Acta, 1962, Vol. 27, pp. 31-36.

(4) R. W. Perkins, "An Anticoincidence Shielded-Multidimensional Gamma-Ray Spectrometer," Nuclear Instruments and Methods, vol. 33, pp. 71-76, 1964.

(5) R. W. Perkins, D. E. Robertson and H. G. Rieck. 1965. "Pacific Northwest Laboratory Annual Report 1965. Physical Sciences. BNWL-2352 p. 108.

(6) N. A. Wogman, D. E. Robertson and R. W. Perkins 1967. Large detector anticoincidence shield multidimensional gamma-ray spectrometry. Nuclear Inst. and Methods, vol. 50, p. 1-10.

CHEMICAL COMPOSITION OF TROPICAL RIVERS

Introduction

Low salinities and suspended loads predominate in tropical rivers; these are considered to be the result of a combination of low intensity of weathering and high precipitation, and runoff.

Gibbs (1965) in his studies on the Amazon considers relief to be the most significant parameter in the control of the concentrational and compositional parameters of the geochemistry of the Amazon River Basin. Relief determines, to a great extent, the dissolved and suspended solid contents, particle size, and many of the concentrations of various minerals constituting suspended solids.

Under Gibbs's classification, the tropical environment basins are composed of rain forest and savannas. The rain forest possesses varying rock types, low to moderate relief, consistently high temperature and precipitation, and dense broadleaf evergreen vegetation. The savanna is usually underlain by igneous and metamorphic rocks, has a moderate relief, and a wider seasonal variation in temperature and precipitation. Absolute comparisons between the two environments are difficult, but it would seem that the areas bounding Routes 17 and 25 would fall into this classification.

One of the factors introducing temporal variability in the concentration of elements in rivers is the relative contribution derived from ground water and surface runoff. In general, ground water to a river tends to be relatively stable with the contribution from surface runoff producing the variable. In the dry season in Panama and Colombia, the river flows are maintained mainly by ground water, though some rainfall does occur. In the wet season, when rainfall is heavy and concentrated in short periods of time, the contribution to the flow is almost entirely by runoff. Ground water, by its contact with the soil, is usually more concentrated in elements than surface runoff though on these routes, the high cation exchange capacity of the litter-soil profile and nature of the run-off pattern may tend to negate this.

In addition to the temporal variations, there are also spatial differences. In any large river system, the composition of the dissolved elements will be different in the various head-water tributaries. These local variations, which reflect differences in rainfall and geology of various parts of the drainage system, tend to cancel each other as one proceeds downstream. Consequently, there is a tendency for the composition of the water in the downstream parts of the rivers to resemble one another.

Because of the temporal and spatial variability of river waters, single grab samples cannot give a precise measure of the elemental chemistry. In areas such as Panama and Colombia with very great seasonal and daily variations in rainfall, such values may be in error to some degree. However, we have improved to some degree upon the single sample which has often been used to characterize major rivers, especially in tropical and arctic regions (Livingstone 1963), by taking samples in the so-called wet and dry seasons. Arrangements for systematic sampling at three of the Hydro stations were made, but few reliable samples were made available.

Much of the published water chemistry data available for comparison ignores suspended material. Also, the variability of filtration procedures and their effect upon the chemical composition of the filtrate leaves a lot to be desired in sampling methods and treatment. Our studies have indicated where some of these errors might arise. In the absence of exhaustive data on the sorptive capacity and saturation of river silts, it is impossible to evaluate this error since it will vary from element to element and river to river. For the principal components in most rivers it is not of great importance, though such readily ionized and extremely soluble elements such as sodium and caesium can be bound in considerable quantity to fine mineral particles by various sorption processes.

Low suspended solids are typical of most tropical environment rivers. Gibbs (1965) considers this to be a result of a combination of low intensity of weathering, high and consistent precipitation, and runoff in areas of low relief covered with vegetation of a high density erosion-protective type.

From the limited data available, and from field observations, the suspended load can change markedly over a period of a few hours from ten's to hundreds of mg/l correlated with the rapid rise and fall in the level and flow of the river after rainstorms.

In the high density vegetation areas, it was observed that there is little runoff across the surface of the ground during heavy rainstorms. Charnell (1968) considers that the interflow, that flow occurring in the subsurface, is fast, but it does not transport large amounts of sediments. It is likely, therefore, that the origin of suspended solids is by channel erosion rather than sheet runoff.

The results of this study indicate that the freshwaters of the areas bounding Routes 17 and 25 contain low concentrations of dissolved and suspended solids, and in elemental composition are not strikingly different than other freshwaters of the world. In fact, they are well within the world-wide average for almost all measured elements.

The complete lack of data for the rivers in these areas enhances the value of these data in terms of the geochemistry of tropical fresh waters, though it should be recognized that the collection of geochemical data was not a major objective. However, in terms of this feasibility study, it was necessary to survey the waters of these areas in order to characterize the elemental composition of the various watersheds. The overall data suggests a fairly constant elemental composition and while there are differences in elemental concentrations in water from the various stations and during the "wet" and "dry" seasons, the use of the mean values derived should not introduce any serious errors into the major conclusions of this study.

In the initial stages of this program, it was anticipated that data on river flow, sedimentation rates, and suspended solids would be available from the systematic program of the IOCS Hydrology Program. Such data, in combination with our data, would have provided an estimate of the rate and quantity of elements transported out of the freshwater system to the estuarine and marine environments. However, the limited data that has become available was too late for inclusion in this report.

The overall mean values of the concentration of elements in water collected at all stations on Routes 17 and 25, the Rio Sabanas, with comparative published data are presented in Table 5 . The mean values ($\bar{x}$), standard deviation (S.D.), standard error (S.E.), by route and by season, are presented for water in Table 3 ; for water plus suspended solids, Table 7, and for suspended solids, Table 8.

The data for the individual samples appear in Appendix I .

Discussion Of Elements Analyzed

A. WATER

Sodium

The overall mean for stations on Route 17 and 25 was 7.4 mg/l, which can be compared with a world wide concentration of 6.3 mg/l. The Rio Sabanas (Station 21) showed levels that were two or three times the mean value.

There is an overall tendency for the sodium to be higher in the "dry" season than in the "wet" season. On Route 25, there was a gradual decrease in sodium concentrations towards the mouth.

The suspended solids did not contribute an appreciable amount of sodium to the total load.

Potassium

The concentration of potassium in water tended to be lower than the world average, with the exception of the Rio Sabanas (Station 21). Route 17 samples were higher than those from Route 25 by a factor of two. There was no obvious difference between "wet" and "dry" seasons. The potassium concentration of suspended solids was low.

The relationship between potassium and calcium is compared in Figure K/Ca, together with other published data (Preston, et al., 1967).

Copper

The concentrations of copper were low in the waters from both routes, with higher values in the Rio Sabanas (Station 21). In general, the levels were near to the limit of detection. There was no obvious difference between seasons. The suspended solids contribute between 10 and 50% to the total load.

Magnesium

The overall mean of 5.1 mg/l is comparable with the world average. The Rio Sabanas (Station 21) was higher by about a factor of two. There was little difference between Routes in the "wet season, though in the "dry" season, Route 25 tended to have higher concentrations. The suspended solids have little effect upon the total dissolved load, with the exception of the Rio Sabanas.

Calcium

The concentrations of calcium (15.1 mg/l) in the waters of Routes 17 and 25 are comparable with the world average. The Rio Sabanas concentration was about five times as high as the mean of all stations. In the "wet" season, the samples from the Rio Salaqui (Stations 59-61) showed a marked increase. This could be a reflection of the geology of the area. Apart from this area, there was no apparent increase in concentration. The suspended solids contribute only a small percentage to the total dissolved solids load.

Zinc

The concentrations of zinc measured by activation analysis in this study are comparable with world wide levels. The concentrations range over at least an order of magnitude with marked increases in the "wet" season, but no obvious differences between the routes. The suspended solid concentrations made little contribution to the total elemental load. There are marked differences between values derived by chemical-physical methods and neutron activation.

Strontium

The concentrations of strontium appear to be comparable to the world wide average. Concentrations tend to be higher on Route 17 than Route 25, with the Rio Sabanas conspicuous for its high level. There is no apparent difference between the seasons. The suspended solid contribution to the total load is small. In Figure S, the relationships between strontium and calcium in mg/l and the atom ratio and calcium concentrations are presented. Overall, there is a tendency for Route 17 samples to have more strontium, relative to calcium than in the temperate regions, while Route 25 samples tend to have the same or less.

Chromium

The concentrations of chromium showed no marked differences between routes, and are comparable with previously published values. On both routes, there is an indication of increased concentrations in the "wet" season. The reverse was noted for the Azuero Peninsula samples (Stations 29-31). The contribution from suspended solids is slight.

Phosphorus

The measured phosphorus levels in the waters from Routes 17 and 25 were extremely low. In part, we suspect that sampling and treatment methods were not adequate for these low levels. Because of this, it is not possible to evaluate differences.

Manganese

The overall mean for Routes 17 and 25 are directly comparable with the world wide average. In the "wet season, the values for both routes are comparable; however, the "dry" season values for Route 17 indicate a reduction by a factor of five.

Relatively high values of manganese were found in the Cienega de Perancho (Station 66) and the Sautata Swamp (Station 65) of 0.087 mg/l and 0.21 mg/l respectively. Livingstone (1963) reports a value of 0.20 mg/l from a swamp system in the Congo. It has been suggested that these high values may be due to drainage from areas with high values in vegetation. Manganese is also known to be high in waters with a high reductive capacity.

The mean Iron to Manganese ratio in all the waters sampled is 6.3:1 as compared with a world wide ratio of 42:1. Ratios of 1.3:1 and 0.9:1 were found in the African swamps as compared with 3.9:1 for the Atrato swamp.

Iron

As is to be expected, the iron concentrations are very variable due to treatment and storage effects. Overall, there is little difference between routes with a tendency for values to be higher in the "wet" season. Suspended solids contribute markedly to the total elemental load.

Trace Elements

For the trace elements, Cobalt, Silver, Caesium, Zinc, Scandium, Antimony, Mercury, Tungsten and Gold, the only comparative data is that of Kharker et al., (1967). For Silver, Scandium, Antimony and Cobalt, our data is comparable. The values in this study for caesium were considerably lower, with most samples being below the limit of detection (<0.05 μg/l).

B. SUSPENDED SOLIDS

The suspended solids contribute very little to the trace elements load. The suspended solids data are presented in Tables 9 and 10 . by station and season. These values can only be used as an index of the loading. They do indicate that the concentration is low, and are comparable with the data of Gibbs (1965).

The chemical and activation analysis data indicates that the contribution of suspended solids to the chemical composition of the rivers is low. Livingstone (1963)considers that the quantity of suspended material usually carried by rivers is hardly an order of magnitude greater than the quantity of dissolved material. As only a small fraction of the suspended material consists of absorbed components, estimates for these and primarily geochemical studies of the total amount of mineral water carried by rivers are unlikely to be in serious error.

Correlations between the chemical composition of the water and suspended solids are not obvious. Studies by Turekian and Scott (1967) on 12 rivers in the U. S., one in France, and one in South America indicate that the trace element composition of the dissolved trace elements is not reflected in the composition of the suspended load, and that the elements carried in suspended materials may to a large degree be in inert positions.

INTERPRETATION

Interpretation of the water and suspended solids data must be subject to several reservations. First the sampling procedure involving grab samples, field or laboratory filtration, field and laboratory centrifugation etc., must be considered. Secondly, the analytical techniques, whether chemical-physical or by neutron activation, and their limitations need to be recognized.

The logistical problems of getting samples from the sampling areas to the laboratory in the U.S. were difficult to overcome, and errors due to adsorption on container walls, etc., despite pretreatment, could not be entirely avoided. The samples collected in "Dry" Season II, and especially those required for activation analysis, were frozen as soon as possible after collection and field treatment. This improved treatment may account for some of the apparent differences between seasons.

As an example of this, data on a month's storage in a polyethelene bottle at room temperature of Columbia River water is presented in Table 11. However, we were not justified in using this data to correct the route samples.

The use of membrane filters is standard practice in water chemistry for removal of suspended solids. Robertson (1968) has shown that these filters contain significant concentrations of the trace elements and can introduce a serious error into the determinations. Hence, all the samples for activation analysis were centrifuged to remove the suspended solids and may not, therefore, be strictly comparable with the chemical-physical determinations.

TABLE 5. STABLE ELEMENT CONCENTRATION FROM PANAMA AND COLOMBIA WITH COMPARATIVE WORLD WIDE DATA

(Chemical Analysis)

Water	mg/l Na	mg/l K	mg/l Cu	mg/l Mg	mg/l Ca	mg/l Zn	mg/l Sr	mg/l Cr	mg/l P	mg/l Mn	mg/l Fe
All Stations in Panama and Colombia (except Stn. 21)[1]	7.36	0.86	.006	5.13	15.14	<0.014	0.055	<0.018	0.011	0.017	0.103
Rio Sabanas (Stn. 21)[1]	17.10	4.00	0.082	10.30	69.80	0.013	0.340	0.007	----	0.020	0.295
Columbia River[2]	1.92	0.72	<0.003	4.34	21.96	0.122	0.082	<0.010	0.061	<0.010	0.026
Columbia River[3]	1.70	0.70	0.01	4.10	19.80	0.013	----	----	----	0.001	0.030
Columbia River[4]	1.77	0.70	0.002	4.30	20.10	0.018	----	----	----	0.0014	0.068
World[5] [6]	6.3	2.3	0.01	4.1	15.0	0.01	0.08	0.0002	0.005	0.012	0.67
N. America[5]	9.0	1.4	---	5.0	21.0	---	----	-----	----	----	0.16
S. America[5]	4.0	2.0	---	1.5	7.2	---	----	-----	----	----	1.4
Europe[5]	5.4	1.7	---	5.6	31.1	---	----	-----	----	----	0.8
Africa[5]	11.0	---	---	3.8	12.5	---	----	-----	----	----	1.3

(1) This study
(2) Cushing (12/12/63)
(3) Cushing (1962, yearly average)
(4) Silker (1964)
(5) Livingstone (1963)
(6) Bowen (1966)
(7) Kharkar et al. (1967)

CONTINUED

TABLE 5. STABLE ELEMENT CONCENTRATIONS IN WATERS FROM PANAMA AND COLOMBIA WITH COMPARABLE WORLD WIDE DATA

(Activation Analysis)

Water	mg/l Na	μg/l Co	μg/l Ag	μg/l Cs	μg/l Zn	μg/l Sc	μg/l Sb	μg/l Hg	mg/l W	mg/l Au	μg/l U	μg/l Rb	μg/l Se	μg/l Cr	μg/l Mo
All Stations in Panama and Colombia (except Stn. 21)[1]	7.75	0.29	0.39	<0.049	0.025	0.086	0.086	<0.04	<1.0	<0.1	---	---	---	---	---
Rio Sabanas (Stn. 21)[1]	18.7	0.21	0.12	0.03	25.0	0.11	0.056	<0.04	<1.0	<0.1	---	---	---	---	---
Columbia River[2]		0.069	---	0.04	---	0.032	---	---	<1.0	<0.1	<83.0	---	---	---	---
Amazon[7]		0.12	0.23	0.019	---	---	4.90	---	---	---	---	1.55	0.21	2.46	0.44
All Rivers[7]		0.19	0.30	0.020	---	---	1.9	---	---	---	---	1.1	0.20	1.4	1.80
World (Chemical)[5] [6]		0.9	0.13	0.2	10.0	---	---	0.08	---	<0.06	1.0	1.5	20.0		

[1] This study

[2] Cushing (12/12/63)

[5] Livingstone (1963)

[6] Bowen (1966)

[7] Kharkar et al. (1967)

TABLE 6 . CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

(Chemical Analysis)

Water

		mg/l Na	mg/l K	mg/l Cu	mg/l Mg	mg/l Ca	mg/l Zn	mg/l Sr	mg/l Cr	mg/l P	mg/l Mn	mg/l Fe
Dry Seasons												
Route 17	x̄	9.64	1.08	<.004	4.96	15.30	<.018	.068	<.026	.013	.016	.103
	S.D.	5.35	.35	.002	2.13	10.06	.031	.046	.043	.016	.020	.144
	S.E.	.90	.06	.000	.36	1.70	.005	.008	.007	.003	.003	.024
	*N	35	35	35	35	35	35	35	35	35	35	35
Rio Sabanas (17)	x̄	28.2	5.22	<.004	15.81	98.0	.008	.491	<.004	<.013	.013	.013
	*N	2	2	2	2	2	2	2	2	2	2	2
Route 25	x̄	6.49	.48	<.006	7.86	14.18	<.015	.032	<.014	.011	.014	.054
	S.D.	2.22	.16	.003	2.88	3.71	.015	.016	.015	.013	.010	.055
	S.E.	.51	.04	.001	.66	.85	.003	.004	.003	.003	.002	.014
	*N	19	19	16	19	19	19	16	19	16	16	16
Wet Season												
Route 17	x̄	7.24	1.04	<.006	3.97	16.08	<.010	.060	<.015	.011	.008	.109
	S.D.	2.56	.26	.002	2.07	5.93	.008	.021	.013	.024	.005	.108
	S.E.	.52	.05	.000	.42	1.21	.002	.004	.003	.005	.001	.002
	*N	24	24	24	24	24	24	24	24	24	24	24

*Number of samples.

CONTINUED

CONTINUED

TABLE 5 . CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

(Chemical Analysis)

Water

		mg/l Na	mg/l K	mg/l Cu	mg/l Mg	mg/l Ca	mg/l Zn	mg/l Sr	mg/l Cr	mg/l P	mg/l Mn	mg/l Fe
Rio Sabanas (17)	x̄	11.3	3.25	.009	7.39	54.9	<.013	.242	.012	.018	.034	1.96
	S.D.	.7	.25	.005	.96	5.2	.006	.043	.010	.020	.046	3.92
	S.E.	.4	.14	.003	.55	3.0	.003	.025	.005	.012	.027	2.26
	*N	3	3	3	3	3	3	3	3	3	3	3
Route 25	x̄	4.33	.59	<.008	4.24	14.65	<.011	.044	<.011	.010	.035	.138
	S.D.	1.82	.19	.000	2.11	7.71	.000	.018	.003	.017	.060	.181
	S.E.	.41	.04	.000	.47	1.72	.000	.004	.001	.004	.014	.042
	*N	20	18	20	20	20	20	20	20	19	19	19
All Samples[1]	x̄	7.36	.86	<.006	5.13	15.14	<.014	.055	<.018	.011	.017	.103
	S.D.	4.13	.37	.002	2.64	7.65	.020	.034	.028	.018	.031	.134
	S.E.	.42	.04	.000	.27	.77	.002	.004	.003	.002	.003	.014
	*N	98	96	95	98	98	98	95	98	94	94	94
Rio Sabanas (17)	x̄	18.0	4.04	.007	10.76	72.1	.012	.342	.009	.016	.025	1.182
	S.D.	9.3	1.09	.004	4.70	24.0	.006	.160	.009	.017	.035	2.460
	S.E.	4.2	.49	.002	2.10	10.7	.003	.072	.004	.008	.016	1.100
	*N	5	5	5	5	5	5	5	5	5	5	5

*Number of samples.

[1] Excluding Rio Sabanas

CONTINUED

TABLE 6. CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

) Trace Elements In Water

(Activation Analysis)

		mg/l Na	µg/l Ag	µg/l Cs	µg/l Zn	µg/l Sc	µg/l Sb	µg/l Co
	% Error	10%	35%	---	10%	15%	15%	15%
DRY SEASONS								
Route 17	$\bar{x}$	10.30	.224	<.048	10.25	.004	.110	.205
	S.D.	2.30	.473	.012	9.05	.005	.072	.113
	S.E.	.61	.126	.003	2.42	.001	.019	.030
	*N	14	14	14	14	14	14	14
Rio Sabanas (17)	$\bar{x}$	29.60	.040	.010	4.760	.005	.110	.037
	*N	1	1	1	1	1	1	1
Route 25	$\bar{x}$	7.56	.108	<.050	16.76	.004	.140	.227
	S.D.	2.40	.067	.017	15.97	.001	.126	.236
	S.E.	.80	.021	.005	5.05	--	.040	.075
	*N	9	10	10	10	10	10	10

*Number of Samples

CONTINUED

TABLE 6 . CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

) Trace Elements In Water

(Activation Analysis)

		mg/l Na	µg/l Ag	µg/l Cs	µg/l Zn	µg/l Sc	µg/l Sb	µg/l Co
	% Error	10%	35%	---	10%	15%	15%	15%
WET SEASONS								
Route 17	$\bar{x}$	6.79	.273	<.049	32.29	.069	.400	.325
	S.D.	1.94	.197	.018	19.22	.080	.740	.207
	S.E.	.65	.066	.006	6.40	.027	.247	.069
	*N	9	9	9	8	9	9	8
Rio Sabanas (17)	$\bar{x}$	10.80	.200	<.050	58.00	.220	.030	.380
	*N	1	1	1	1	1	1	1
Route 25	$\bar{x}$	6.25	.765	<.050	41.17	.211	.163	.428
	S.D.	2.38	.910	---	21.88	.371	.180	.478
	S.E.	.03	.221	---	5.65	.090	.044	.116
	*N	17	17	17	15	17	17	17
ALL SAMPLES[1]								
	$\bar{x}$	7.75	.394	<.049	25.25	.086	.186	.292
	S.D.	2.79	.642	.013	21.19	.234	.338	.320
	S.E.	.40	.091	.002	3.09	.033	.048	.046
	*N	49	50	50	47	50	50	48

*Number of Samples

[1]Excluding Rio Sabanas

TABLE 7 . CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

(Chemical Analysis)

Water plus Suspended Solids		mg/l Na	mg/l K	mg/l Cu	mg/l Mg	mg/l Ca	mg/l Zn	mg/l Sr	mg/l Cr	mg/l P	mg/l Mn	mg/l Fe
WET I												
Route 17	x̄	---	---	.013	4.48	16.81	.016	---	.018	---	.082	2.62
	S.D.	---	---	.007	2.12	6.04	.007	---	.016	---	.085	2.80
	S.E.	---	---	.002	.55	1.56	.002	---	.004	---	.022	.72
	*N	---	---	15	15	15	14		15		15	15
Rio Sabanas (17)	x̄	---	---	.200	22.20	68.65	.138	---	.183	---	.643	69.61
	*N	---	---	1	1	1	1	---	1	---	1	1
Route 25	x̄	---	---	.010	1.79	5.80	.015	---	.004	---	.006	1.81
	*N	---	---	1	1	1	1	---	1	---	1	1
DRY II												
Route 17	x̄	9.69	1.299	.018	5.61	14.31	.019	.088	.012	.088	.058	2.88
	S.D.	3.16	.457	.012	1.24	2.18	.010	.079	.003	.093	.049	3.21
	S.E.	1.41	.205	.005	.55	.97	.005	.035	.001	.042	.022	1.44
	*N	5	5	5	5	5	5	5	5	5	5	5
Rio Sabanas (17)	x̄	27.27	5.358	.006	16.675	102.202	.011	.387	.005	.050	.035	.362
	*N	1	1	1	1	1	1	1	1	1	1	1
Route 25	x̄	7.49	.535	.009	8.83	14.79	<.009	<.029	.013	.030	.018	.402
	S.D.	1.67	.109	.002	2.47	2.64	.003	.006	.006	.012	.007	.503
	S.E.	.63	.041	.001	.93	1.00	.001	.002	.002	.005	.003	.190
	*N	7	7	7	7	7	7	7	7	7	7	7

*Number of Samples.

CONTINUED

TABLE 7 . CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

(Activation Analysis)

Supernatant Fraction plus Suspended Solids		mg/l Na	μg/l Ag	μg/l Cs	μg/l Zn	μg/l Sc	μg/l Sb	μg/l Co
Dry Season I								
Route 17	$\bar{x}$	12.55	.130	.037	11.80	.072	.237	.305
	S.D.	5.03	.065	.026	8.73	.126	.247	.347
	S.E.	1.30	.017	.007	2.33	.033	.064	.089
	*N	15	15	15	14	15	15	15
Rio Sabanas (17)	$\bar{x}$	42.50	.100	.040	21.00	.300	.820	.400
	*N	1	1	1	1	1	1	1
Route 25	$\bar{x}$	7.62	.120	.040	10.63	.351	.597	.587
	S.D.	3.01	.035	.020	10.98	.453	1.005	.630
	S.E.	1.35	.020	.010	5.49	.227	.503	.315
	*N	5	3	4	4	4	4	4
Wet Season I								
Route 17	$\bar{x}$	13.56	.970	.679	113.89	8.080	.827	7.479
	S.D.	6.60	1.357	1.418	120.96	15.546	.776	14.023
	S.E.	3.30	.452	.473	40.32	5.182	.259	4.674
	*N	9	9	9	9	9	9	9

*Number of samples.

CONTINUED

TABLE 7 . CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

(Activation Analysis)

Supernatant Fraction plus Suspended Solids

		mg/l Na	μg/l Ag	μg/l Cs	μg/l Zn	μg/l Sc	μg/l Sb	μg/l Co
Rio Sabanas (17)	$\bar{x}$	42.60	2.900	4.800	340.00	42.000	6.200	25.000
	*N	1	1	1	1	1	1	1
Route 24	$\bar{x}$	8.61	.758	.176	109.29	.934	.300	2.196
	S.D.	4.00	.913	.448	123.10	1.590	.282	3.190
	S.E.	.97	.221	.109	29.85	.386	.068	.774
	*N	17	17	17	17	17	17	17
Dry Season II								
	$\bar{x}$	6.83	**	**	**	**	**	**
	S.D.	3.55						
	S.E.	1.59						
	*N	5						

*Number of Samples.

**Data Not Available by 6/1/68.

TABLE 8 . CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

(Chemical Analysis Based on Dry Weight)

Suspended Solids

		mg/l Na	mg/l K	mg/l Cu	mg/l Mg	mg/l Ca	mg/l Zn	mg/l Sr	mg/l Cr	mg/l P	mg/l Mn	mg/l Fe
WET I												
Route 17	$\bar{x}$	---	---	.008	.469	.417	.006	---	<.003	---	.076	2.556
	S.D.	---	---	.006	.544	.524	.006	---	.002	---	.085	2.769
	S.E.	---	---	.002	.141	.135	.002	---	.001	---	.022	.715
	*N	---	---	15	15	15	15	---	15	---	15	15
Rio Sabanas (17)	$\bar{x}$	---	---	.195	15.700	8.650	.128	---	.182	---	.640	69.600
	*N	---	---	1	1	1	1	---	1	---	1	1
Route 25	$\bar{x}$	---	---	.005	.391	.195	.005	---	<.003	---	.005	1.76
	*N	---	---	1	1	1	1	---	1	---	1	1
DRY II												
Route 17	$\bar{x}$	.072	.216	.008	.718	.523	.008	<.003	.005	.074	.051	2.780
	S.D.	.091	.243	.011	.809	.595	.011	.003	.004	.091	.053	3.249
	S.E.	.041	.109	.005	.362	.266	.005	.002	.002	.041	.024	1.453
	*N	5	5	5	5	5	5	3	5	5	5	5
Rio Sabanas (17)	$\bar{x}$	.000	.029	.000	.055	.202	.001	.004	.002	2.450	.017	.190
	*N	1	1	1	1	1	1	1	1	1	1	1
Route 25	$\bar{x}$	.011	.055	<.001	.066	.052	.0003	<.003	.002	.018	.008	.334
	S.D.	.017	.050	---	.075	.041	.0009	.002	.001	.012	.005	.462
	S.E.	.006	.022	---	.028	.016	.0003	.001	<.001	.004	.002	.175
	*N	7	7	7	7	7	7	7	7	7	7	7

*Number of Samples.

FIGURES SHOWING CONCENTRATION OF ELEMENTS IN RIVER WATERS OF PANAMA AND COLOMBIA

Sequence of Figures

Na
K
Mg
Ca
Zn
Sr
Cr
Mn
Fe
Ag
Sc
Sb
Co
Sr/Ca
Atoms Sr/Ca
K/Ca

Key to Figures

D - Dry season (D_1 - Dry I; D_2 - Dry II)

W - Wet Season

A) Δ - world wide mean

X - overall mean for Panama and Colombia

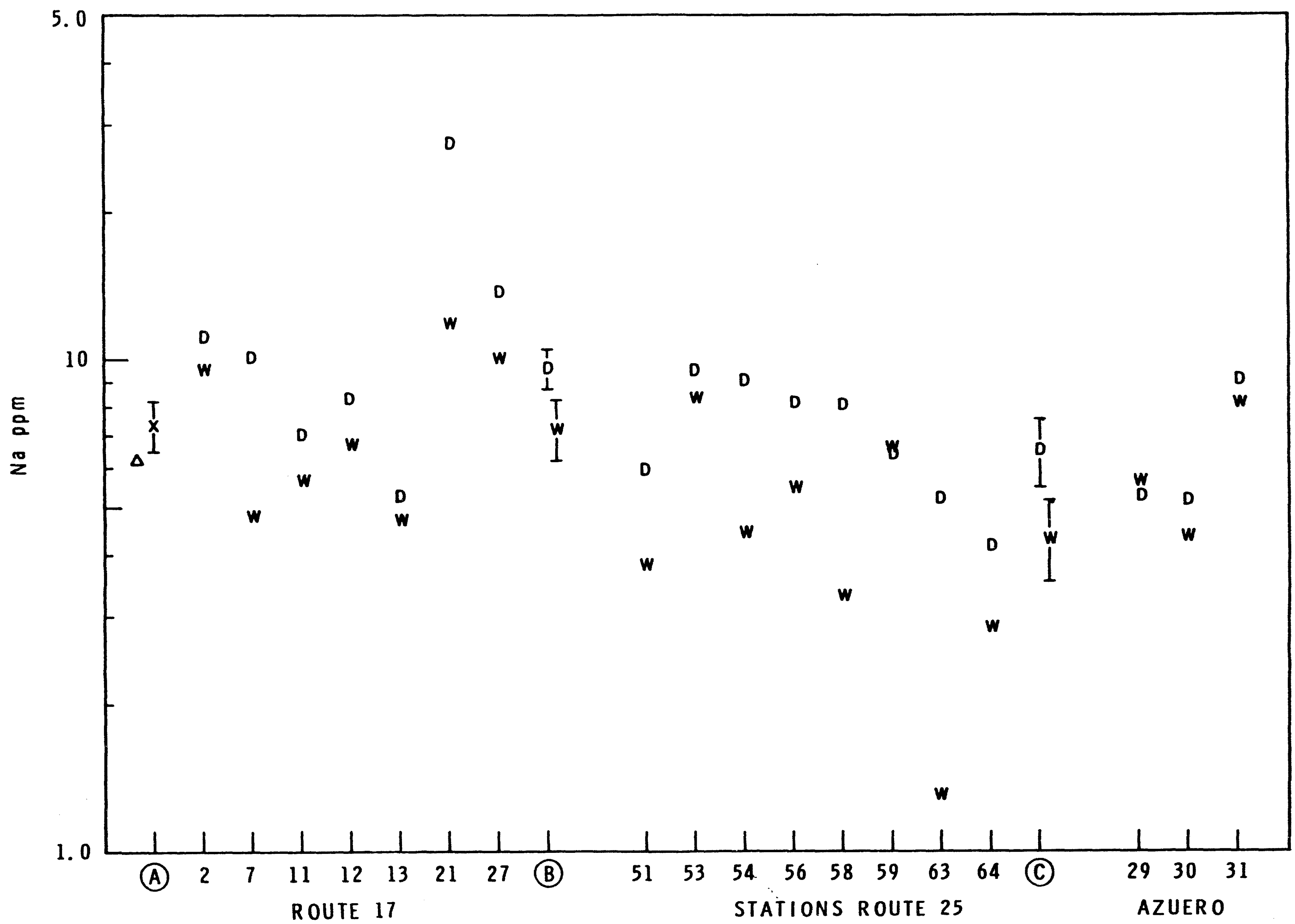
for all stations and all seasons except Station 21.

B) Means for wet and dry season ± the standard errors of the mean

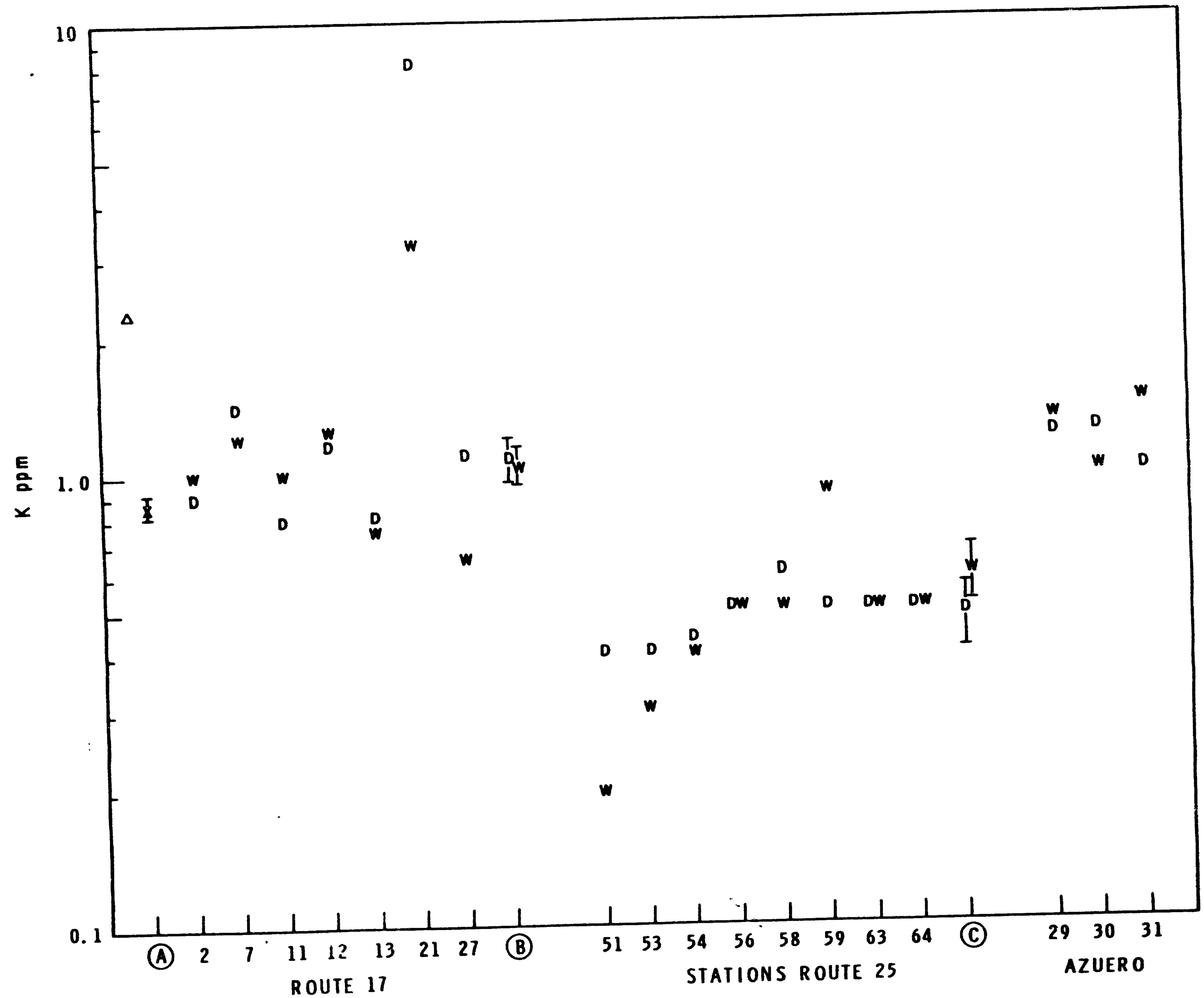
for all stations and Route 17 except Station 21.

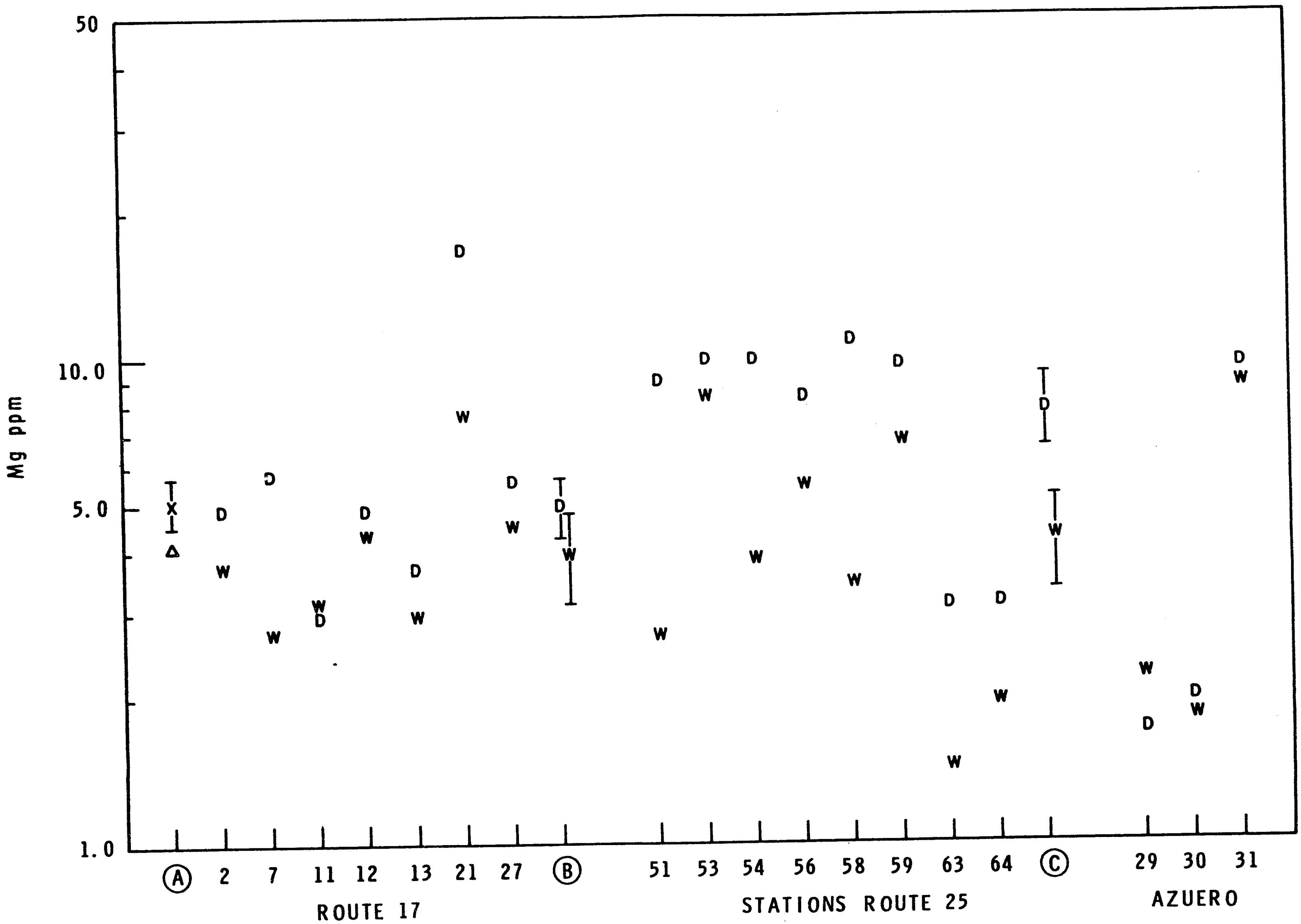
C) Means for the wet and dry season ± the standard error of the mean

for all stations, Route 25.

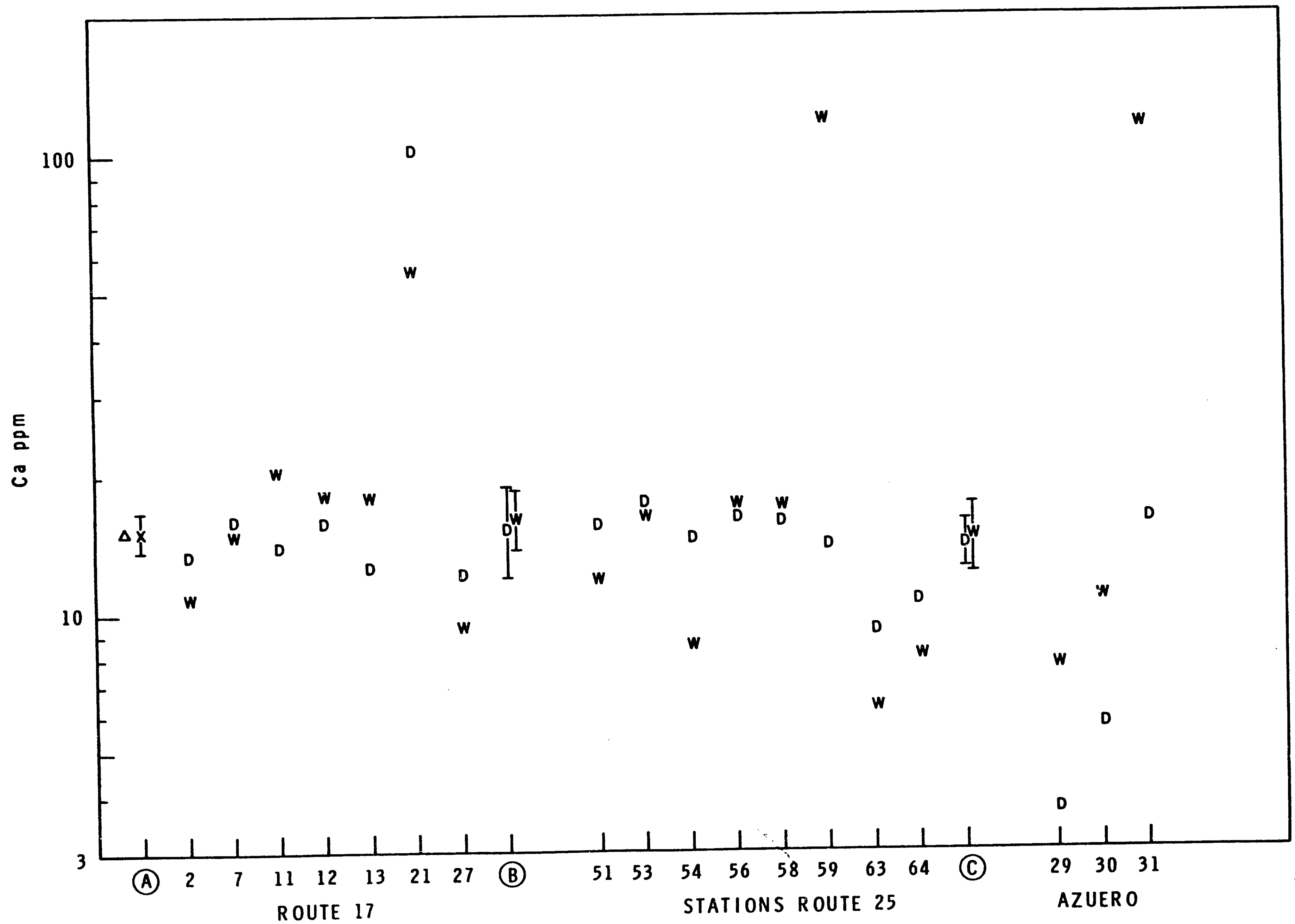


5.0
10
1.0
Na ppm
A 2 7 11 12 13 21 27 B 51 53 54 56 58 59 63 64 C 29 30 31
ROUTE 17
STATIONS ROUTE 25
AZUERO

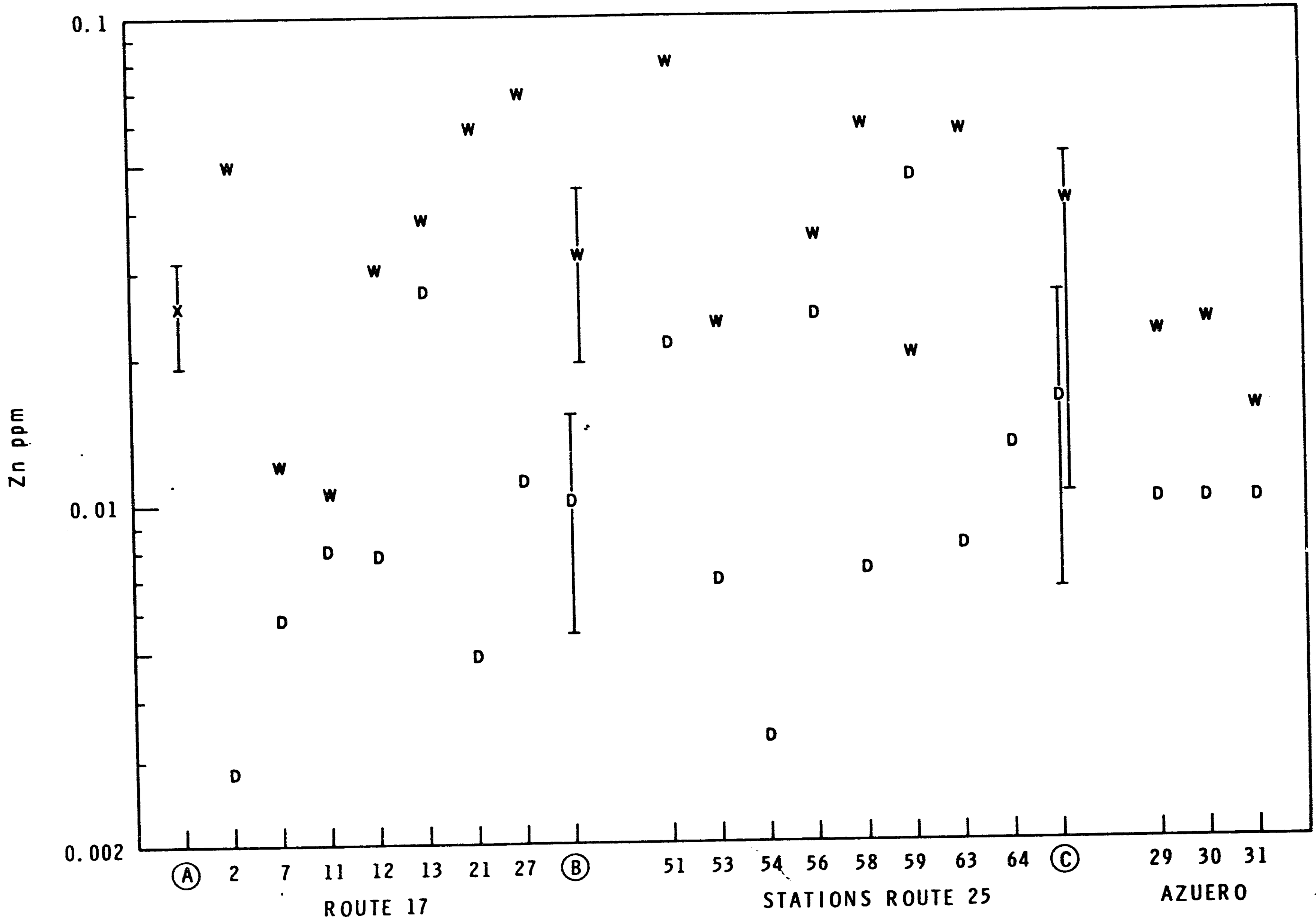

K ppm
10
1.0
0.1
Ⓐ 2 7 11 12 13 21 27 Ⓑ
ROUTE 17
51 53 54 56 58 59 63 64 Ⓒ
STATIONS ROUTE 25
29 30 31
AZUERO



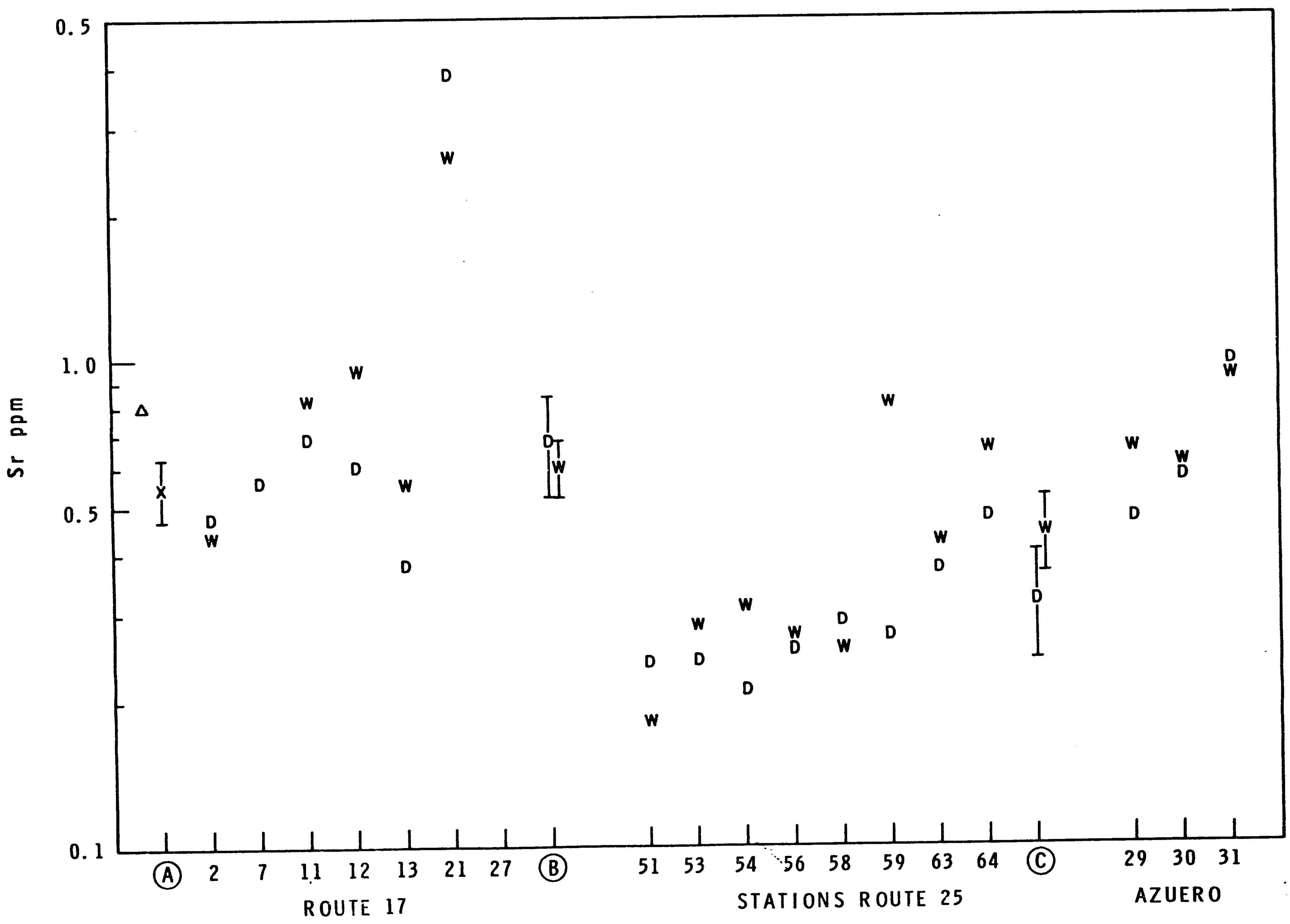
Mg ppm
50
10.0
5.0
1.0
A
2
7
11
12
13
21
27
B
51
53
54
56
58
59
63
64
C
29
30
31
ROUTE 17
STATIONS ROUTE 25
AZUERO



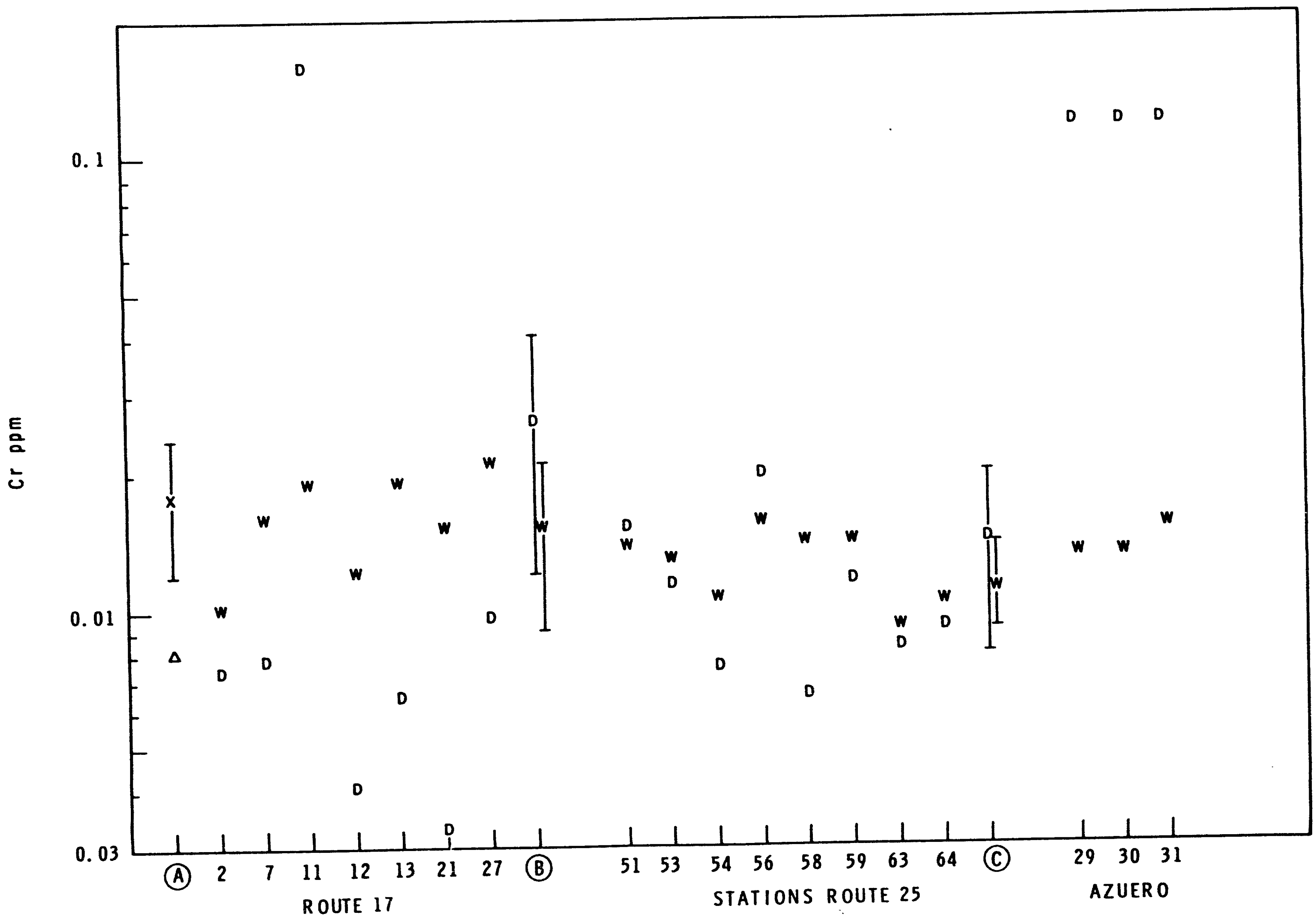
Ca ppm
100
10
3
A
2
7
11
12
13
21
27
B
51
53
54
56
58
59
63
64
C
29
30
31
ROUTE 17
STATIONS ROUTE 25
AZUERO

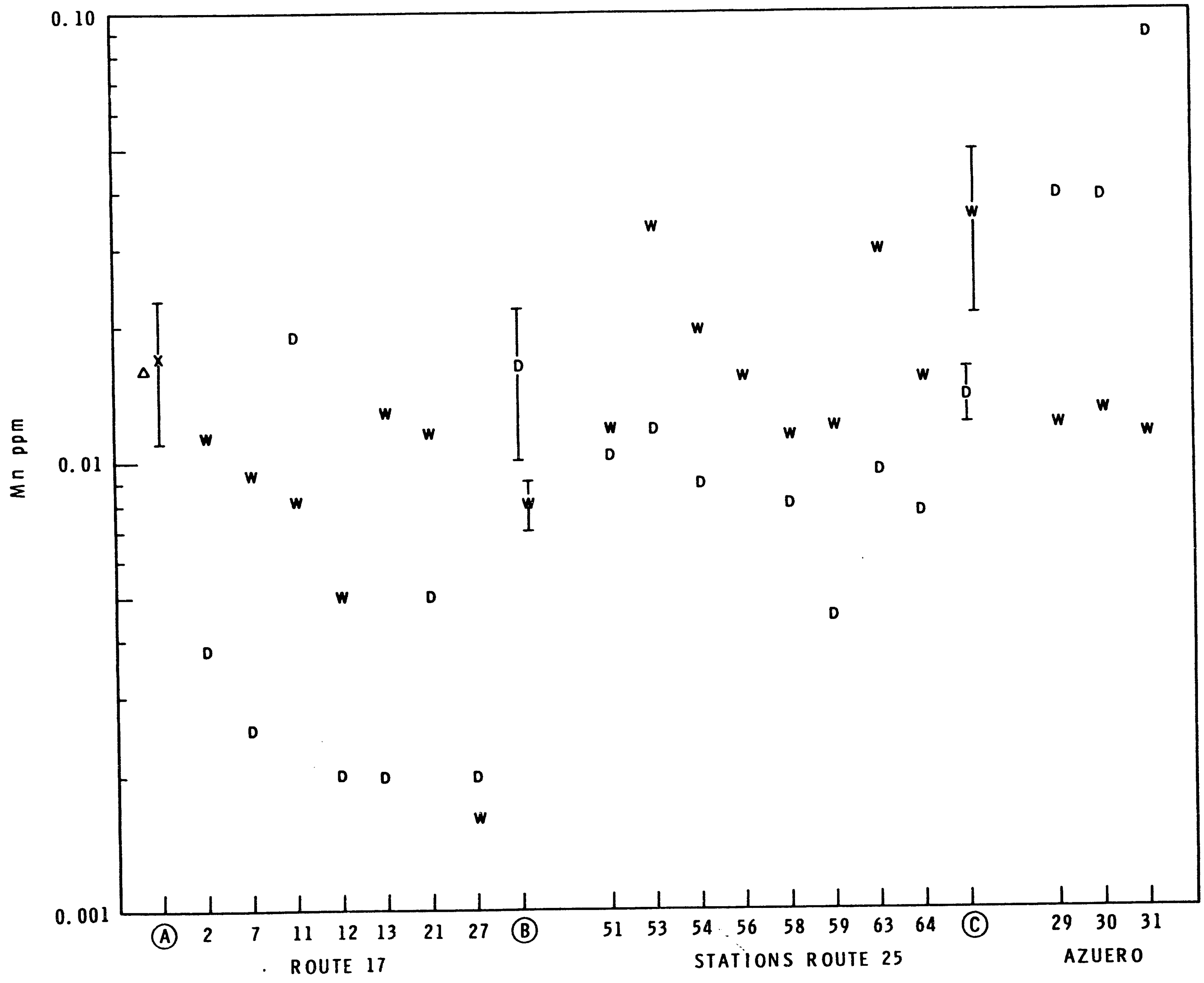


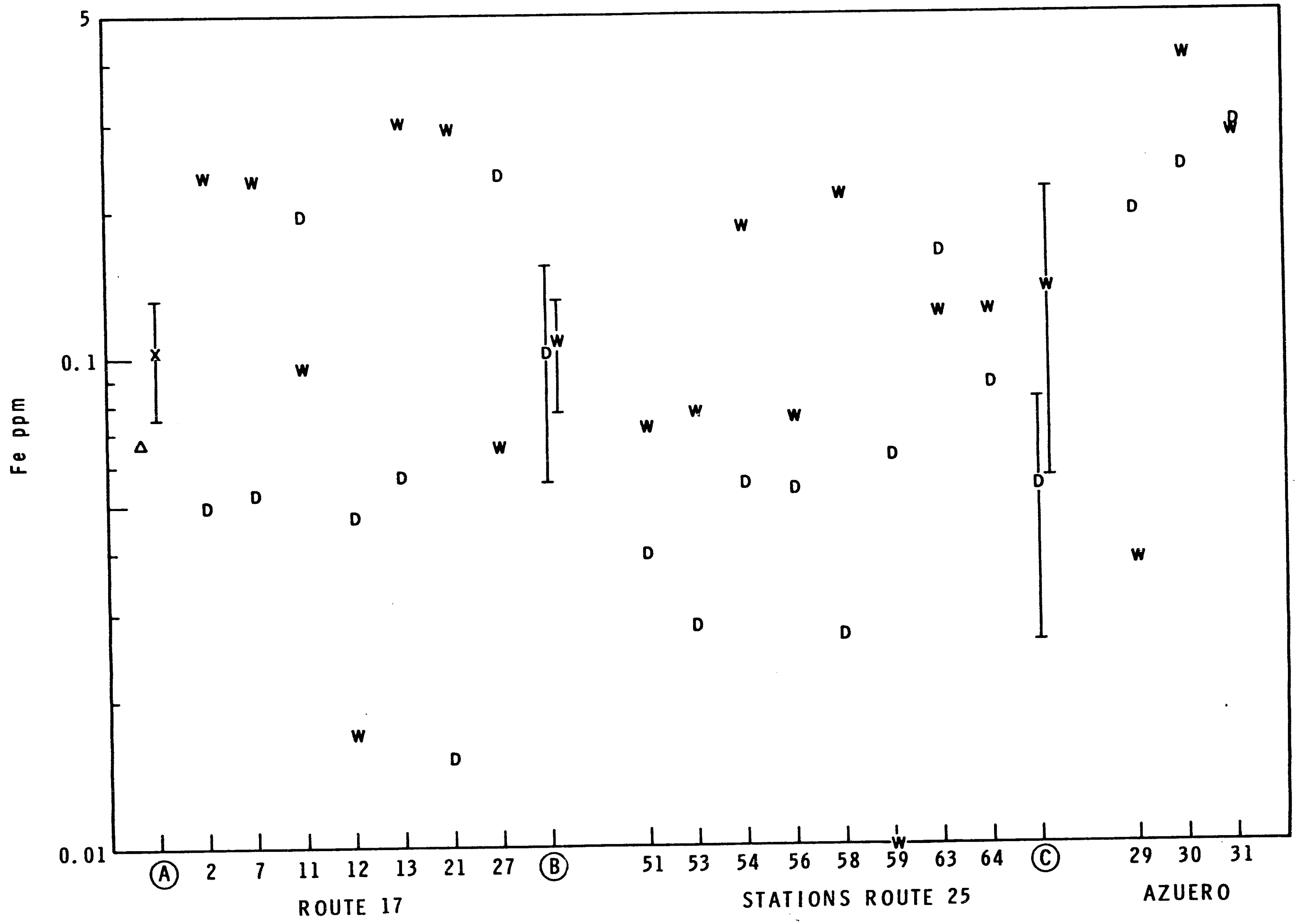
0.1
0.01
0.002
Zn ppm
A
2
7
11
12
13
21
27
B
51
53
54
56
58
59
63
64
C
29
30
31
ROUTE 17
STATIONS ROUTE 25
AZUERO



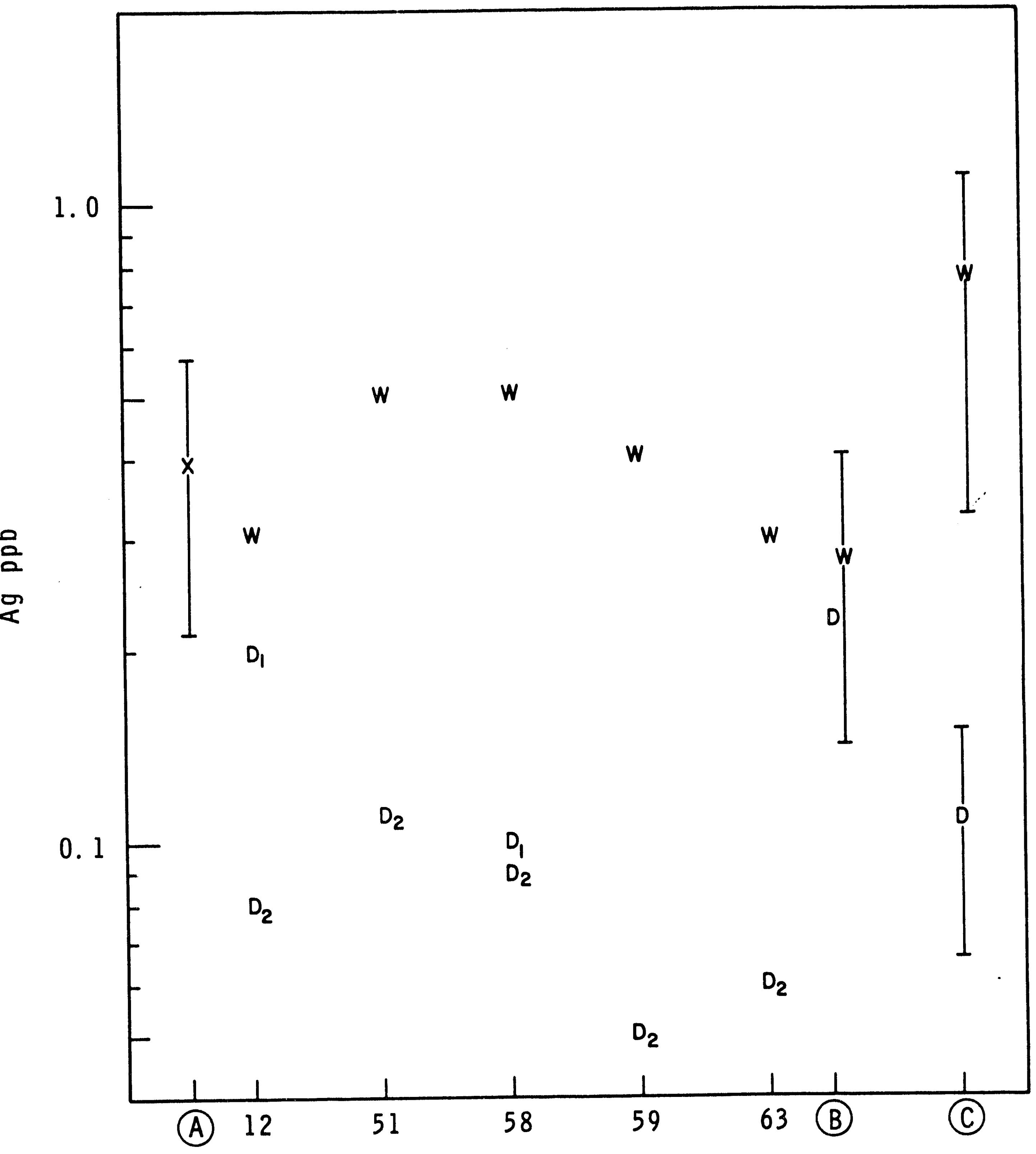
Sr ppm
0.5
1.0
0.5
0.1
A
2
7
11
12
13
21
27
B
51
53
54
56
58
59
63
64
C
29
30
31
ROUTE 17
STATIONS ROUTE 25
AZUERO


Cr ppm
0.1
0.01
0.03
A
2
7
11
12
13
21
27
B
51
53
54
56
58
59
63
64
C
29
30
31
ROUTE 17
STATIONS ROUTE 25
AZUERO

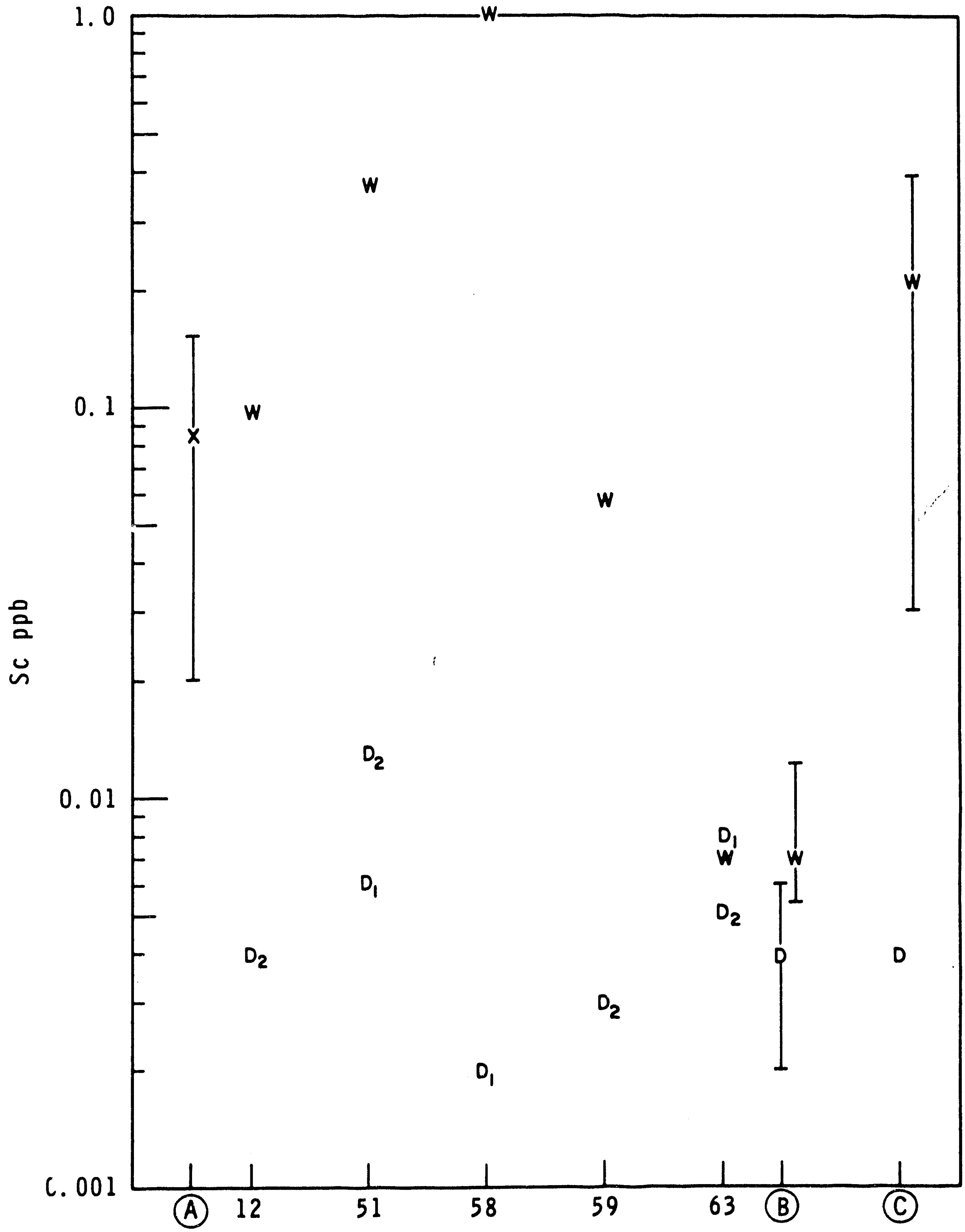

Mn ppm
0.10
0.01
0.001
A
2
7
11
12
13
21
27
B
51
53
54
56
58
59
63
64
C
29
30
31
ROUTE 17
STATIONS ROUTE 25
AZUERO

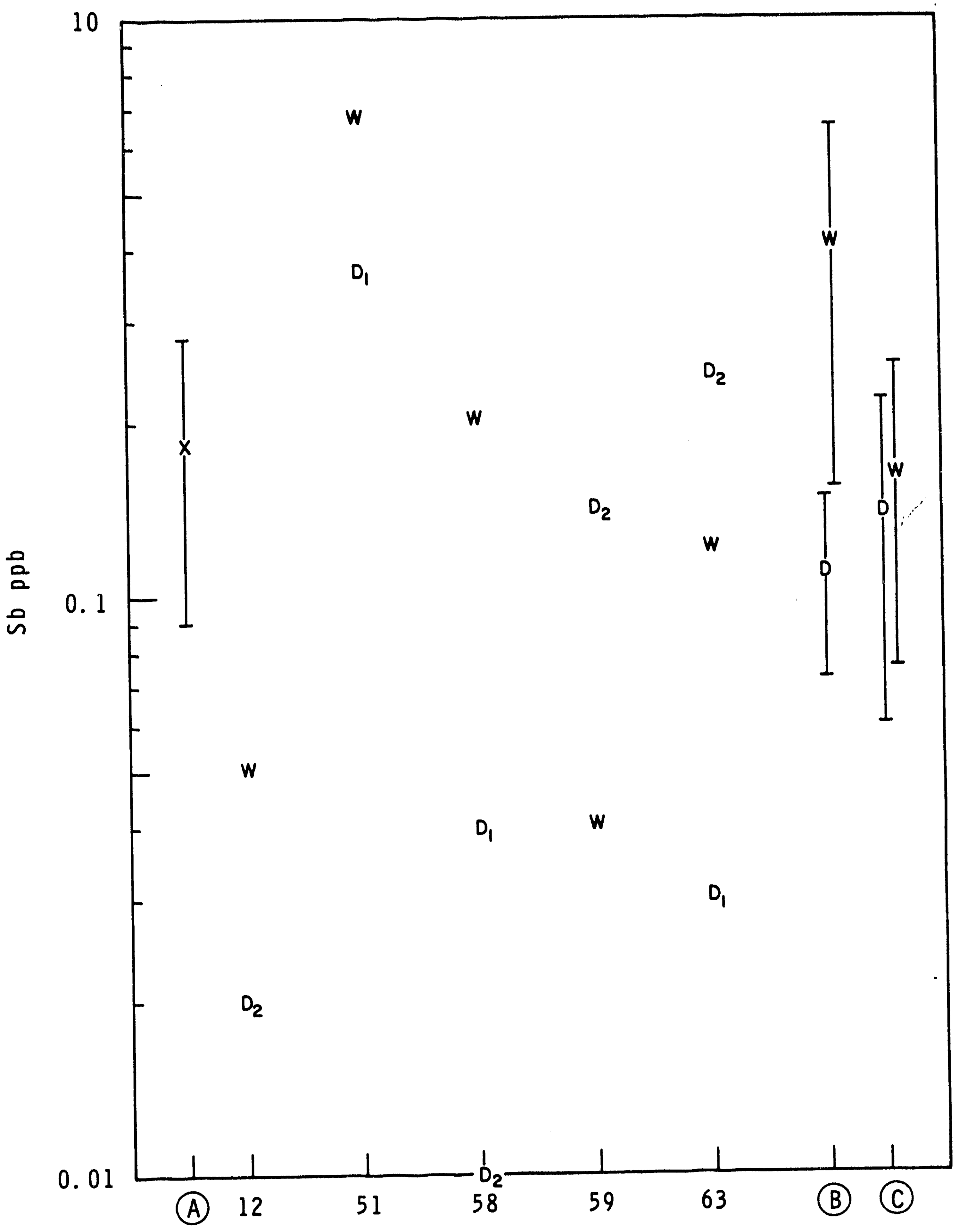


Fe ppm
5
0.1
0.01
A
2
7
11
12
13
21
27
B
51
53
54
56
58
59
63
64
C
29
30
31
ROUTE 17
STATIONS ROUTE 25
AZUERO

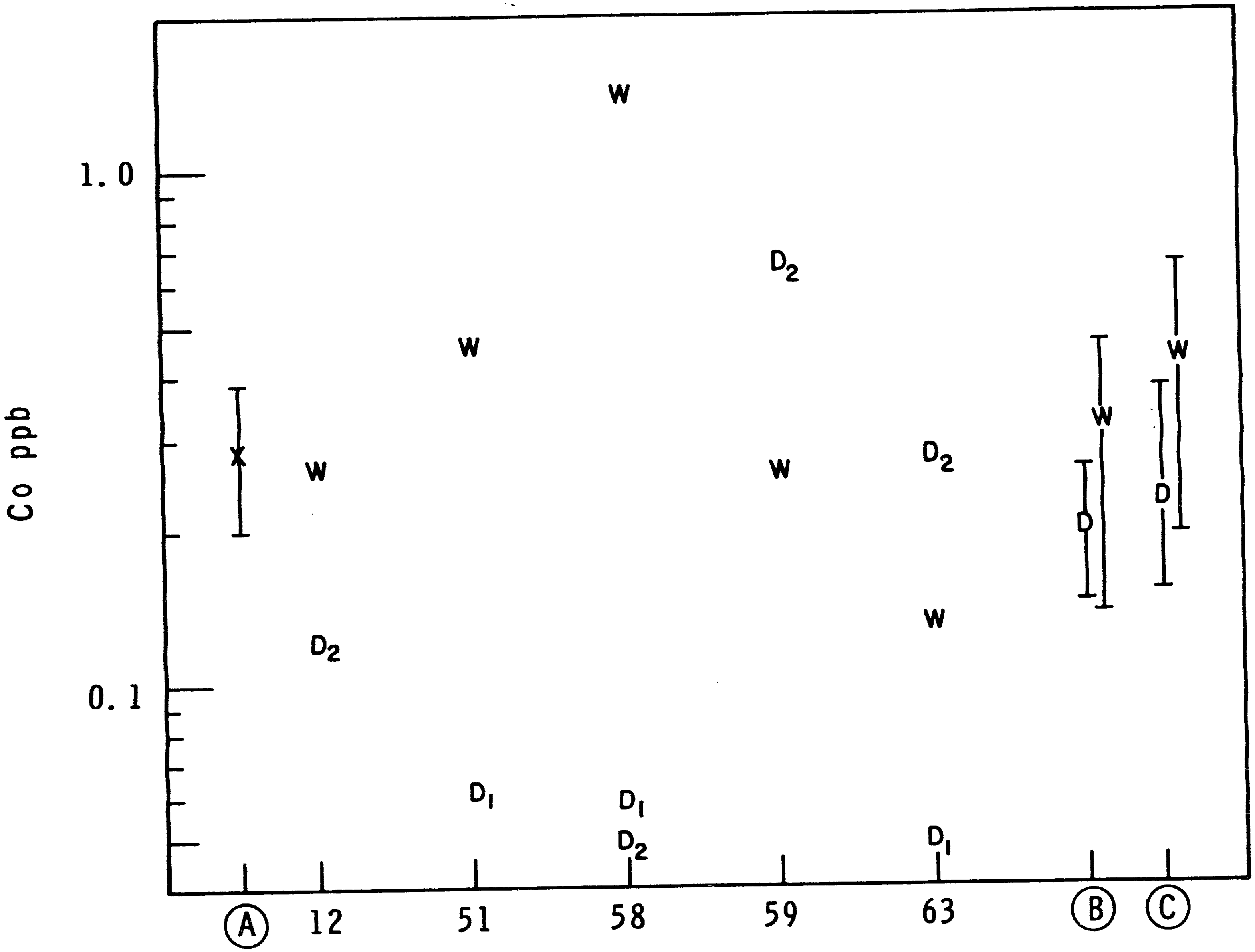


Ag ppb
1.0
0.1
A
12
51
58
59
63
B
C

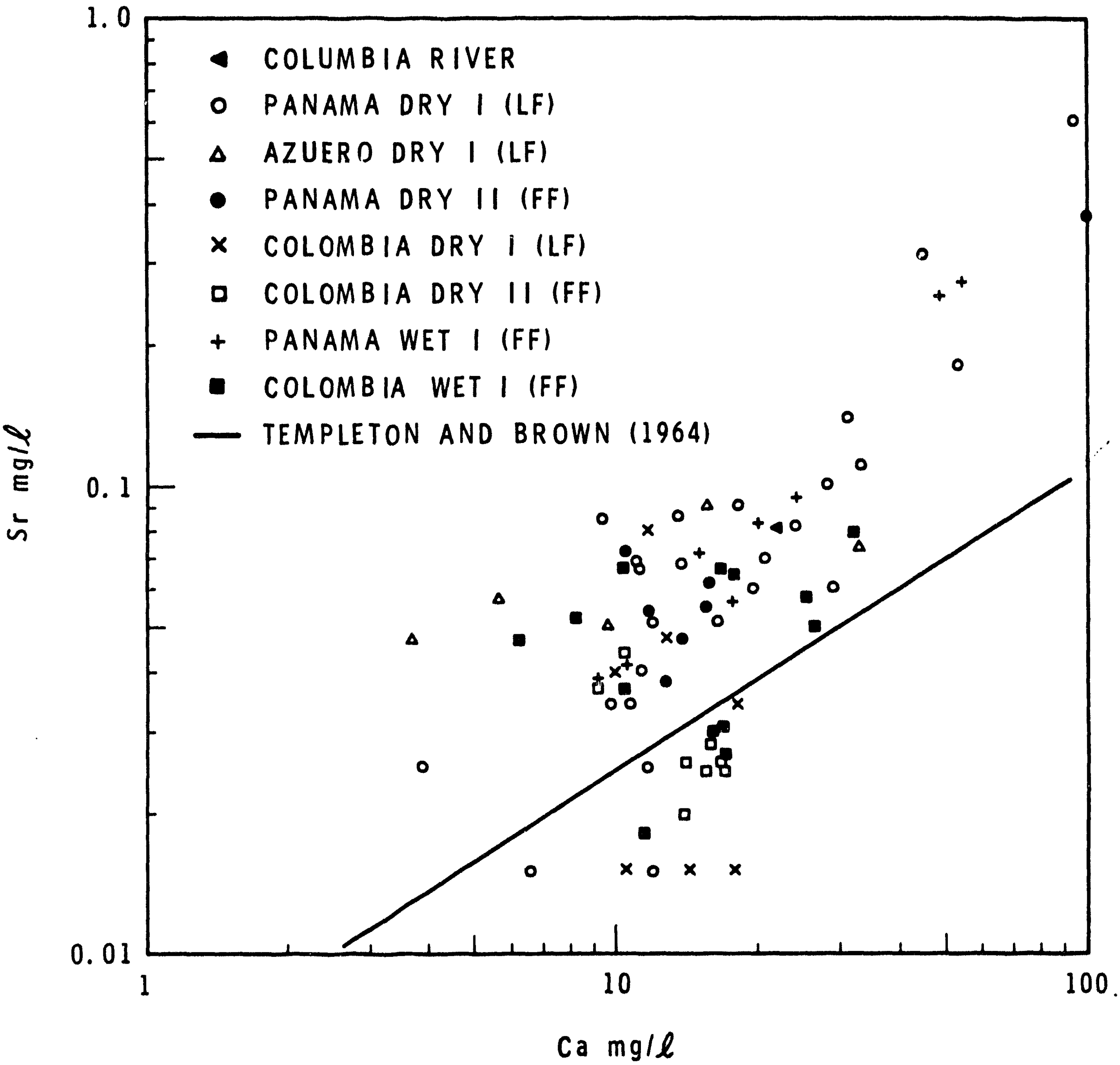

Sc ppb
1.0
0.1
0.01
C.001
A
12
51
58
59
63
B
C
W
X
D
D1
D2

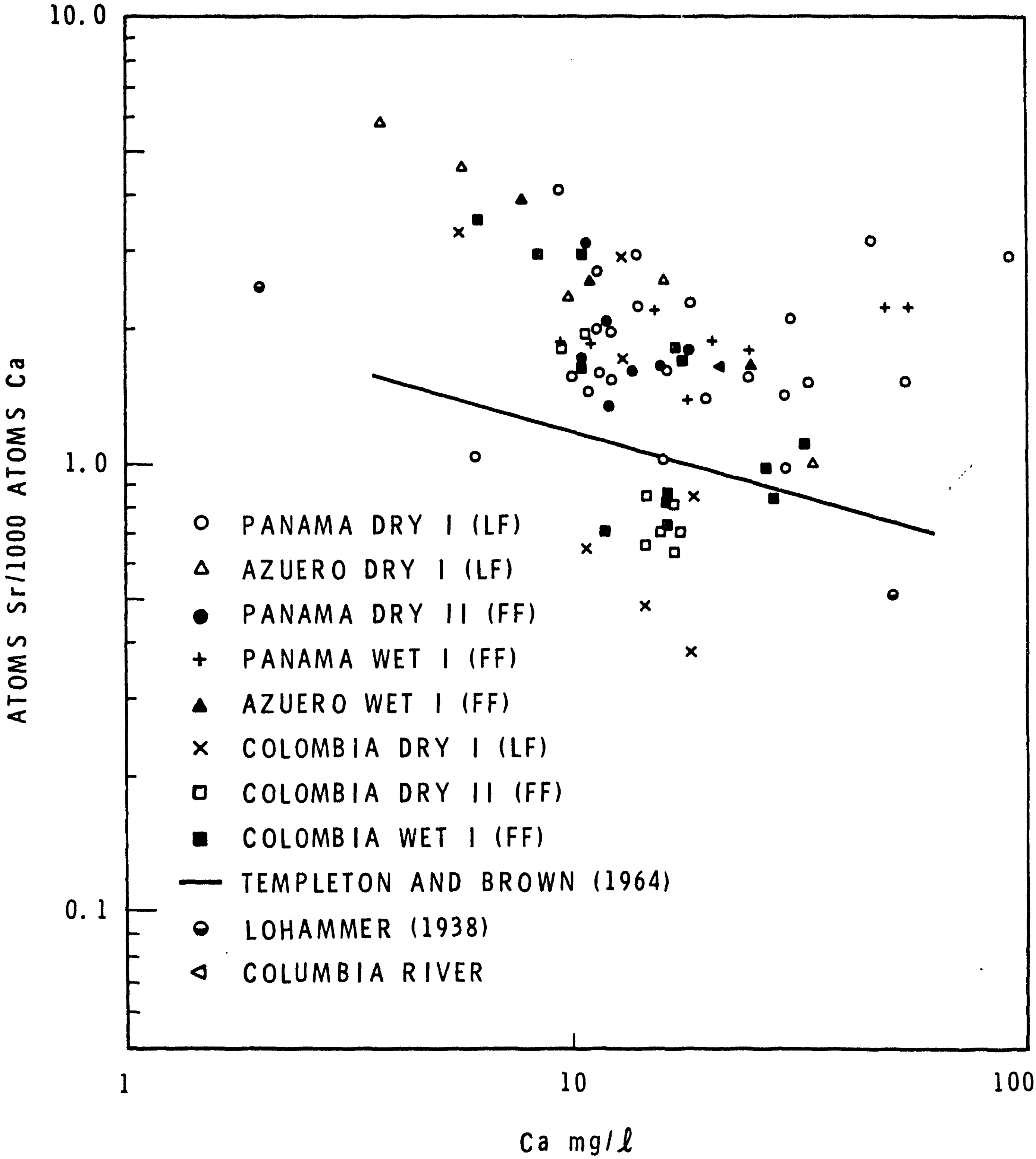


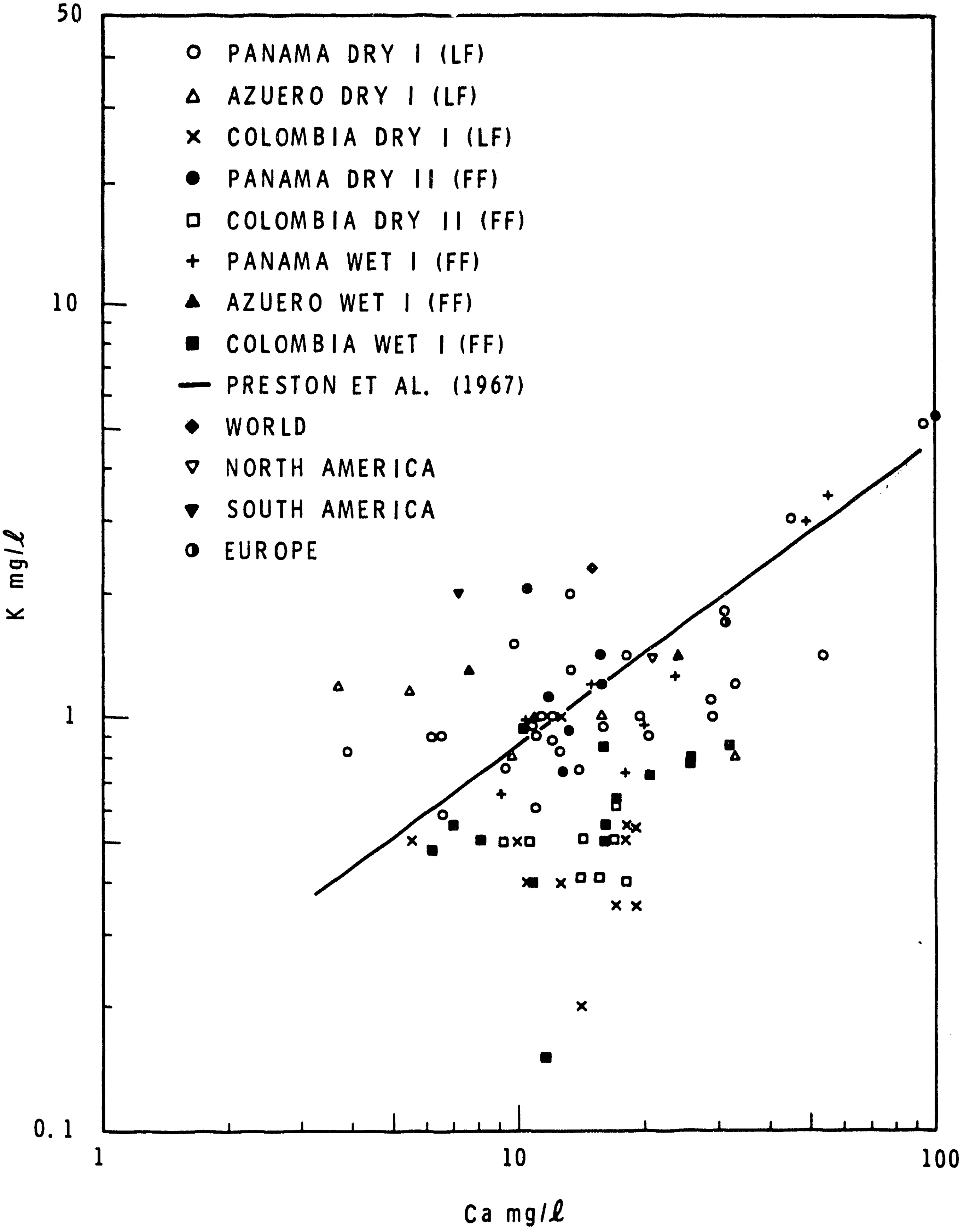
Sb ppb
10
0.1
0.01
W
D1
D2
X
D
A
12
51
58
59
63
B
C



Co ppb
1.0
0.1
A
12
51
58
59
63
B
C


COLUMBIA RIVER
PANAMA DRY I (LF)
AZUERO DRY I (LF)
PANAMA DRY II (FF)
COLOMBIA DRY I (LF)
COLOMBIA DRY II (FF)
PANAMA WET I (FF)
COLOMBIA WET I (FF)
TEMPLETON AND BROWN (1964)
1.0
0.1
0.01
Sr mg/ℓ
1
10
100
Ca mg/ℓ


10.0
1.0
0.1
ATOMS Sr/1000 ATOMS Ca
1
10
100
Ca mg/ℓ
PANAMA DRY I (LF)
AZUERO DRY I (LF)
PANAMA DRY II (FF)
PANAMA WET I (FF)
AZUERO WET I (FF)
COLOMBIA DRY I (LF)
COLOMBIA DRY II (FF)
COLOMBIA WET I (FF)
TEMPLETON AND BROWN (1964)
LOHAMMER (1938)
COLUMBIA RIVER



PANAMA DRY I (LF)
AZUERO DRY I (LF)
COLOMBIA DRY I (LF)
PANAMA DRY II (FF)
COLOMBIA DRY II (FF)
PANAMA WET I (FF)
AZUERO WET I (FF)
COLOMBIA WET I (FF)
PRESTON ET AL. (1967)
WORLD
NORTH AMERICA
SOUTH AMERICA
EUROPE
50
10
1
0.1
1
10
100
K mg/ℓ
Ca mg/ℓ

TABLE 9. CONCENTRATION OF SUSPENDED SOLIDS IN SAMPLES FROM PANAMA AND COLOMBIA

WET I

a) Panama

Station	River	Date	Suspended Solids mg/l
7	Chucunaque El Real	9-7-67	357
11	Chico	9-8-67	158
12	Tuira	9-7-67	100
13	Pirre	9-8-67	22
21	Sabanas	9-7-67	1609
27	Narka	9-10-67	39
29	Grande	9-5-67	32
30	Santa Maria	9-5-67	84
31	La Villa	9-6-67	119

b) Colombia

Station	River	Date	Suspended Solids mg/l
51	Curiche	8-29-67	187
52	Jurado	9-1-67	115
53	Truando	8-27-67	89
54	Truando	8-26-67	399
54	Truando	8-26-67	681
56	Nercua	8-27-67	10
57	Nercua	8-27-67	148
58	Salado	8-26-67	157
59	Salaqui	8-28-67	62
60	Salaqui	8-28-67	121
61	Salaqui	8-28-67	253
62	Atrato	8-31-67	242
63	Atrato	8-31-67	167
64	Atrato	8-31-67	102
65	Sautata Swamp	8-29-67	27
66	Cienega de Perancho	8-29-67	23
67	Perancho	8-29-67	58

TABLE 9. CONCENTRATION OF SUSPENDED SOLIDS IN SAMPLES FROM PANAMA AND COLOMBIA

DRY II

a) Panama

Station	River	Date	Suspended Solids mg/l
2	Chucunaque	2-6-68	7.
7	Chucunaque	2-6-68	760.
27	Narka	2-14-68	14.
26	Aligandi	2-15-68	25.
13	Pirre	2-6-68	97.
21	Sabanas	2-15-68	54.
12	Tuira	2-6-68	466.

b) Colombia

53	Truando	2-12-68	233.
54	Truando	2-8-68	45.
51	Curiche	2-14-68	47.
56	Nercua	2-12-68	191.
58	Salado	2-8-68	35.
59	Salaqui	2-10-68	28.
63	Atrato	2-9-68	35.

TABLE 10. PER CENT LIGHT TRANSMISSION IN WATER SAMPLES FROM PANAMA

Wet Season I

Station Number	River	Site	Date	% Light Transmission
1	Rio Chucunaque	Nura	9-2-67	72.00
7	Rio Chucunaque	El Real	9-7-67	3.00
11	Rio Chico		9-8-67	50.00
12	Rio Tuira		9-7-67	10.00
13	Rio Pirre		9-8-67	81.00
21	Rio Sabanas		9-7-67	.53
27	Rio Narka		9-10-67	93.00
29	Rio Grande		9-5-67	95.00
30	Rio Santa Maria		9-5-67	22.00
31	Rio La Villa		9-6-67	29.00

TABLE 11. CONCENTRATION OF ELEMENTS IN SAMPLES FROM THE COLUMBIA RIVER, U.S.A.

(Chemical Analysis)

I) WATER

		mg/l Na	mg/l K	mg/l Cu	mg/l Mg	mg/l Ca	mg/l Zn	mg/l Sr	mg/l Cr	mg/l P	mg/l Mn	mg/l Fe
Water collected and analyzed (12/12/67)												
Filtrate	$\bar{x}$	1.92	.72	<.003	4.34	21.96	.122	.082	<.01	.061	<.01	.026
	S.E.	±.07	±.05	±0	±0	±.10	±.009	±.002	±0	±.013	±.00	±.001
Suspended solids	$\bar{x}$	---	---	<.003	.009	.02	<.001	---	<.003	---	.003	.103
	S.E.			±0	±.001	±.00	±.0		±0		±0	±.045
Water plus suspended solids	$\bar{x}$	1.92	.72	<.006	4.34	21.98	.122	.082	<.013	.061	<.013	.129
	S.E.	±.07	±.05	±0	±0	±.10	±.009	±.002	±0	±.013	±0	±.045
Water analyzed 1 Mo. after collection (1/12/68)												
Filtrate	$\bar{x}$	1.83	.80	<.01	3.89	21.38	.013	.076	<.01	.029	<.01	<.01
	S.E.	±.01	±0	±0	±.07	±.07	±.004	±.002	±0	±.009	±0	±0
Suspended solids	$\bar{x}$	.06	<.003	.001	<.005	.005	.003	.0005	.010	.008	.002	.024
	S.E.	±0	±0	±0	±0	±0	±0	±0	±0	±.002	±0	±.004
Water plus suspended solids	$\bar{x}$	1.89	.80	.011	3.90	21.38	.015	.077	.020	.037	.012	.034
	S.E.	±.01	±0	±0	±.07	±.07	±.004	±.002	±0	±.008	±0	±.004

COMPOSITION OF RIVER SEDIMENTS FROM PANAMA AND COLOMBIA

Grab samples of river sediment and one Sabanas shale sample from the Hydro station collected during the 1967 dry season in eastern Panama and western Colombia were analyzed by means of x-ray diffraction, x-ray emission for elemental determination, micropetrographic examination, by cation exchange capacity determination, and by chemical analysis. In addition, samples of river sediment collected from the same area and from western Panama during the 1967 wet season were examined by x-ray diffraction and chemical analysis.

In general, the sediments appeared, based on limited geological data available, to be derived from local rocks and therefore, are essentially typical of the mineral assemblages in the river reaches where they were collected. Exceptions are noted in the detailed discussions that follow.

One property of the river sediments that appears significant from the viewpoint of the retention of radioactive isotopes in the streams is the cation exchange capacity (C.E.C.). The C.E.C. was low for all river samples, with a high of 51 millequivalents per 100 grams being noted from sediments with a high montmorillonite content, which were collected during the dry season. On the other hand, one sample of black shale collected from a bore hole at the Rio Sabana, Hydro station (21) had a C.E.C. of 206 me/100gm. A check on the C.E.C. of river sediments in the Rio Sabana during the wet season revealed a C.E.C. of 70 me/100 gm. This was in contrast to 29 me/100gm for a smaple collected in the same reach during the dry season. Since most samples collected during the wet season have a greater montmorillonite content than do dry season samples, it appears that the C.E.C.'s of river sediments are subject to annual cycles.

Sample Description

a) Panama

Station 18

Rio Setigenti

Gravel sand. Well rounded particles of metasediments. Feldspar and quartz are the dominant minerals. Magnetite is common in the less than 0.5 mm fraction. Organic fragments are also common. The sediments appear to be derived from local rocks cropping out along the Rio Seteganti.

Station 21

Rio Sabanas

Medium-coarse sand. This sample was collected in an area characterized by shale with interbeds of dolomite and calcareous sandstone. The coarser fraction consists of well-rounded quartz rich metasediments with probably originated in the northern reaches of the Rio Sabanas or its tributaries. The finer matrix consists of montmorillonite and calcite of local origin. There are minor quantities of magnetite and a trace of gold. There are numerous snail shells in the 0.5 to 0.1 mm fraction.

Station 14

Rio Uruseca

Coarse sand. Well-rounded grains of intermediate igneous rocks or of metasediments. Quartz, montmorillonite and magnetite abundant. Minor quantities of feldspar. These sediments appear to have been derived from local rocks.

Station 16

Rio Balsas

Fine sand. Well-rounded quartzose fragments with dark iron staining. Quartz, montmorillonite, feldspar and magnetite are abundant. Some wood fragments in all size fractions. The mineral assemblage of this sample should by typical of the upper reaches of the Rio Balsas. Feldspar and magnetite are probably less abundant in the lower reaches of the stream. The upper Balsas flows through an area of igneous, metamorphic and sedimentary rock; the lower river transects a region of shales with interbeds of sandstone and dolomitic limestone.

Station 24

Rio Kunnti

Gravel sand. Weathered intermediate igneous rocks or metasediments with abundant quartz and feldspar. The mineral composition of these sediments should be typical of that found in stream deposits along the Rio Kunnti. Over one-half of the 0.1-0.05 mm fraction is composed of a square plate-like organic particle, low in specific gravity and with a cross-checked pattern.

Station 25

Rio Cuadi

Medium-coarse sand. Dominantly well-rounded quartzose particles of intermediate igneous rocks or of metasediments. Some montmorillonite; minor feldspar, calcite, olivene and magnetite. Some pollens and organic fragments in the less than 0.05 mm fraction.

Station 19

Rio Mogue

Gravel sand. Well-rounded grains of intermediate igneous rocks or of metasediments. Quartz, magnetite and feldspar are abundant in the greater than 50 μ fraction. Feldspar is dominant in the less than 50 μ fraction, but is associated with quartz and montmorillonite. This mineral assemblage can be expected to be typical of the sediments in the Rio Mogue, with the exception of the lowlands in the lower reaches of the stream.

Station 20

Rio Sambu

Gravel sand. Rounded to subangular grains of intermediate igenous composition. Some free quartz, calcite and fine-grained magnetite. This sample was collected in an area of undifferentiated metamorphic, pyroclastic, intrusine and extrusine igneous rocks.

Station 27

Rio Narka

Medium sand. Dominantly well-rounded quartz and feldspar grains. Some montmorillonite, olivene, fibrous serpentine and magnetite.

Station 28

Rio Sabalo

Gravel sand. Rounded to subangular weathered grains of intermediate igneous rocks or of metasediments. Quartz, feldspar and montmorillonite abundant. Pyroxene and magnetite common. Minor calcite and muscovite.

Station 22

Rio Congo

Gravel sand. Angular to subangular grains of intermediate igneous rocks. Feldspar abundant. Quartz crystals in the form of perfect hexagonal dipyramids are common. This sample comes from an area where the rock types are known to change frequently in a distance of a few kilometers. Consequently, this mineral assemblage may not be typical of those encountered along the Rio Congo.

Station 11

Rio Chico

Fine sand. Well-rounded quartz and feldspar sand. Magnetite abundant with angular grains. Montmorillonite abundant in the less than

100 μ fraction. Minor muscovite, calcite and flourite. This sample comes from an area of interbedded sandstones, limestones and shales. The mineral assemblage is probably typical of the Rio Chico with the exception of the uppermost reaches.

Station 10

Rio Tupisa

Medium-fine sand. Angular to subangular grains composed principally of quartz, feldspar and magnetite. There is a trace of gold in the less than 50 μ fraction. The mineral assemblage of this sample and the angular nature of the grains indicate that the materials were transported only a short distance from the parent rock before deposition. The rocks in the area cut by the lower Tupisa are primarily sandstone interbedded with conglomerates, shales and limestones. If the local rocks contain arkoses or similar sediments, then this sample is not atypical of the river deposits in the lower reaches of the Rio Tupisa. On the other hand, if the local sedimentary rocks have rounded grains and lack heavy minerals, the this represents an anomally. There are a few organic fragments similar to the cross-checked, square platelets observed at Station 24.

Station 5

Rio Chucunaque - above Yaviza

Fine sand. Weathered metasediments. Quartz is dominant but feldspar and magnetite are also abundant. Montmorillonite common in the less than 50 μ fraction. Some calcite, muscovite and olivene. This sample is similar to Station 10 in mineral composition; however; chemical weathering is further advanced in this sample than at Station 10. The sampling sites were approximately 2 kilometers apart.

Station 8

Rio Morti-Hydro

Medium sand. Unusual sample is that both well-rounded and angular grains are abundant. Almost all of the greater than 1.0 mm fraction and one-half of 1.0 to 0.5 mm fraction are organic fragments. Feldspar, quartz and montmorillonite are abundant. Particles of intermediate igneous rocks, obsidian, chlorite, olivene, magnetite and stilbite are all common. This sample is probably typical of the sediments in the upper reaches of the Rio Morti, which traverses and area of undifferentiated metamorphic, pyroclastic, intrusive and extrusive igneous rocks and some sedimentary rocks.

Station 2

Rio Chucunaque - Uala

Gravel sand. The gravel is well-rounded and is composed largely of intermediate igneous rocks. The fine-grained materials are predominantly montmorillonite; however, quartz and feldspar are common. This sample is probably representative of the mineral composition of the typical sediments in the Upper Chucunaque.

Station 1

Rio Chucunaque - Nura

Gravel sand. Well-rounded to subangular gravel derived from meta-sediments or rocks of intermediate igneous composition. The fine-grained fraction is composed largely of montmorillonite, feldspar and quartz. This sample was collected closer to the headwaters of the Chucunaque than the sample from Station 1.

Station 9

Rio Membrillo

Medium-fine sand. Well-rounded, iron-stained and weathered. Quartz dominant but feldspar is common. Some hornblende, olivene, rutile and magnetite. This sample appears to be derived from the sandstones, shales and limestones through which the Rio Membrillo flows in all but its uppermost reaches.

Station 15

Rio Yape

Medium-coarse sand. Rounded to subangular grains of metasediments or of sediments which were originally weathered from a nearby igneous source. Quartz, feldspar and montmorillonite are abundant. Some calcite, olivene, enstatite and magnetite. The sample as a whole is strongly magnetic. There is a trace of gold in the less than 0.1 mm fraction. This sample is similar mineralogically to the sample from the Rio Typisa (Station 10).

b) Colombia

Station 58

Rio Salado

Gravel sand. Well-rounded gravel of basic igneous rocks. Magnetite and montmorillonite are abundant in fine fraction. Some quartz and calcite. The coarser materials in this sample appear to be associated more closley with the basaltic igneous rocks in the headwaters region of the Rio Salado than they are with the sediments of the area where the sample was collected.

Station 57

Quebrada Barrial

Coarse sand. Weathered, well-rounded sand composed of plagioclase and magnetite. The fine fraction is predominantly montmorillonite. Stilbite common in fine fraction. These sediments are probably typical of those occurring in the Quebrada Barrial.

Station 67

Rio Perancho

Fine sand. Angular, fine grains of plagioclase, quartz, calcite and magnetite in a matrix of montmorillonite. These constituents are probably typical of the mineral assemblages encountered in sediments of the Rio Perancho.

Station 54

Rio Truando

Medium-fine sand. Dominantly well-rounded quartzose grains. Minor calcite, magnetite, feldspar, rutile and mica. This sample comes from an area characterized by rocks of basaltic composition; consequently, the abundant quartz is probably the result of prolonged weathering. The elemental data, obtained from the less than 0.1 mm fraction, indicate a composition more typical of basaltic rocks.

Station 54

Rio Truando - Falls

Medium-fine sand. Dominantly magnetite. Rutile is also abundant. Magnetite and rutile are heavy minerals that tend to become concentrated due to natural sorting in a stream. Consequently, this sample is probably atypical of the sediments in the upper reaches of the Rio Truando.

Station 63

Rio Atrato

Very fine sand. Quartz is dominant, but feldspar is also abundant in the greater than 50 μ fraction. Montmorillonite is dominant in the less than 50 μ fraction. Minor quantities of magnetite were noted. This sample was obtained from a lowland in the middle reaches of the Rio Atrato. It is probably representative of sediments in the lower reaches of the Rio Truando and the middle reaches of the Rio Atrato.

Station 51

Rio Curiche

Coarse-medium sand. Well-rounded and weathered grains with a dominant basaltic composition. Magnetite is abundant in the fine fraction, plus some quartz and calcite. This sample should by typical of the mineral assemblages encountered in sedimentary deposits of the Rio Curiche.

Station 57

Rio Nercua - Hotspring

Medium-fine sand. Well-rounded grains of intermediate igneous rocks. Mica is common; since this is the only sample of this set to contain significant amounts of mica, the mica may be the result of the alteration of feldspar in the environment of the hotspring. There is abundant magnetite in the less than 0.1 mm fraction, plus some pigeonite and stilbite. Particles having a dolomitic composition are more abundant than in nearby sample from Station 57.

Station 57

Rio Nercua

Medium-fine sand. There is abundant quartz and magnetite. The montmorillonite content is higher and the dolomite content lower than in the sample from the hotspring. This sample appears to be derived from the local sedimentary deposits through which the middle reaches of the Rio Nercua flow rather than from the basaltic rocks in the nearby highlands.

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Inches

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TABLE 12. RIVER SEDIMENT DATA FROM PANAMA AND COLOMBIA

(X-Ray Diffraction Summary)

Key

[xxx]X-ray maxima indicate that this is the predominant mineral in the sample.

[xx]X-ray maxima indicate that this mineral comprises a substantial part of the sample; however, other components are present in about equivalent amounts.

[x]X-ray maxima indicate that this mineral is present but does not comprise a significant part of the sample.

[(1)]Amorphous material is indicated by either the lack of maxima or excessive background. Since Cu radiation was used, iron minerals would tend to be classed as amorphous when in fact they may exhibit some crystallinity.

TABLE 12. RIVER SEDIMENT DATA FROM PANAMA AND COLOMBIA

(X-Ray Diffraction Summary)

a) Panama - Dry I

Station	Size	Amorphous (1)	Montmorillonite	Quartz	Calcite	Magnetite	Feldspar	Olivene
18	<50	xxx						
	>50			xx			xx	
21	<50	xxx						
	>50		x	xx	x		x	x
21	<50		xxx		x		x	
	>50		xx	xx	xx		x	
12	<50		xxx				x	
	>50		xx	xx			xx	
19	<50		x	x			xxx	
	>50			xx			xx	
14	<50	xx	xx	x			x	
	>50		xx	xx				
16	<50		xx	xx			xx	
	>50		x	xxx			x	
24	<50	xxx						
	>50		x	xxx			xx	
25	<50	xxx						
	>50		x	xx				
20	<50							
	>50			xxx			xx	
27	<50		xx	x			xxx	
	>50			xxx	x		xx	
28	<50		xx				xx	
	>50			xx			xx	
22	<50	xxx						
	>50			xxx			xx	
11	<50	xxx	x					
	>50		xx	xx			xx	
10	≤50	xxx						
	≥50			xxx			xx	
5	<50		xx	x			x	
	>50			xxx	x		xx	x

CONTINUED

TABLE 12. RIVER SEDIMENT DATA FROM PANAMA AND COLOMBIA

(X-Ray Diffraction Summary)

a) Panama (continued)

Station	Size	Amorphous (1)	Montmorillonite	Quartz	Calcite	Magnetite	Feldspar	Olivene
8	<50		xx				xx	
	>50		xx	xx			xx	
2	<50		xxx				x	
	>50		xx	xx			xx	
1	<50		xx				xx	
	>50		xx	xx			xx	
9	<50	xxx						
	>50			xx			xx	
15	<50		xx	x			xx	
	>50		xx	xx			xx	

b) Colombia - Dry I

Station	Size	Amorphous (1)	Montmorillonite	Quartz	Calcite	Magnetite	Feldspar	Olivene
58	<50	xxx	xx					
	>50		xx	x	x		xx	
57	<50	xxx	x					
	>50		xx					
67	<50		xxx				xx	
	>50		xx				xxx	
54	<50							
	>50			xxx				
54	<50							
	>50					xxx		
63	<50		xxx					
	>50		x	xxx			xx	
51	<50		xxx					
	>50					xxx		
57	<50							
	>50		xx	x			x	
57	<50	xxx	x					
	>50		xx	xx				

CONTINUED

TABLE 12. RIVER SEDIMENT DATA FROM PANAMA AND COLOMBIA

(X-Ray Diffraction Summary)

a) Panama-Wet I

Station	Size	Amorphous[1]	Montmorillonite	Quartz	Calcite	Magnetite	Feldspar	Olivene	
21	<50		xxx	x			x		
	>50		x	x	x		x		
13	<50		xxx	x					
	>50		x	xx			xx		
12	<50		xxx	x					
	>50		x	xx			x		
27	<50		xx	x			xx		
	>50			xxx			xx		
11	<50		xx	x					
	>50		x	xx	x				
5	<50		xxx	x					
	>50			xx			x		
6	<50		xxx	x					Unidentified max. at 8.93 Å
	>50			xx	x		x		
31	<50	x	x	x			x		
	>50		x	xxx			x		
30	<50		xx	x			x		Unidentified max. at 737 Å
	>50								
29	<50		x	x			x		
	>50		x	xxx			x		

TABLE 12. RIVER SEDIMENT DATA FROM PANAMA AND COLOMBIA

(Elemental Analyses)

a) Panama

Station	Fe_2O_3	TiO_2	CaO	K_2O	SiO_2	Al_2O_3	MgO	ign. loss (%)	Total acc't. for
18	12.70	1.63	3.17	0.43	56.44	9.67	3.43	6.30	98.86
21	7.27	0.60	7.77	1.12	53.73	14.98	2.05	9.19	96.71
21	5.54	0.71	12.23	1.03	43.64	14.03	2.02	4.51	83.71
12	9.53	0.69	5.14	1.00	55.69	15.91	4.13	5.09	92.09
19	9.46	0.85	2.84	0.75	68.73	12.63	1.39	5.46	102.11
14	8.83	.65	2.63	1.10	60.23	17.42	3.46	6.42	100.74
16	15.12	2.29	4.89	0.59	48.90	15.06	6.23	5.63	93.71
24	8.66	0.58	1.91	1.06	61.04	14.28	4.13	4.95	96.61
25	7.60	0.53	4.38	0.97	59.31	12.12	4.80	3.24	92.95
20	9.18	1.21	7.96	0.50	43.90	13.44	2.70	3.89	82.75
27	5.65	0.56	1.65	0.53	72.17	11.26	2.77	2.71	97.30
28	8.42	0.66	4.45	1.03	55.35	13.31	3.41	4.69	91.22
22	6.79	0.65	5.24	0.10	60.87	16.05	3.45	3.59	96.74
11	8.04	0.61	6.00	1.03	57.15	17.22	4.14	3.68	97.87
10	6.41	0.44	1.22	1.20	66.49	12.51	2.06	2.82	93.15
5	7.14	0.45	3.04	1.30	65.89	14.14	3.46	5.72	101.14
8	10.39	0.92	5.04	1.34	51.80	14.29	3.42	4.74	91.94
2	8.51	0.67	3.33	1.20	59.99	15.78	3.45	5.99	98.92
1	8.33	0.69	3.70	1.17	51.92	16.37	2.72	4.69	89.59
9	7.43	0.59	4.86	1.14	61.12	14.88	3.45	3.16	96.63
15	9.00	0.70	6.43	1.03	51.58	18.49	2.74	5.00	94.97

b) Colombia

Station	Fe_2O_3	TiO_2	CaO	K_2O	SiO_2	Al_2O_3	MgO	ign. loss (%)	Total acc't. for
58	10.48	0.76	6.78	0.75	49.07	14.97	7.55	7.25	97.61
57	15.45	1.00	4.11	0.33	41.84	15.84	6.14	4.70	89.41
67	8.17	0.06	6.08	0.32	54.36	19.02	5.52	6.24	100.31
54	15.59	1.60	6.15	0.29	44.98	14.38	10.37	7.12	100.48
54	55.41	17.71	1.88	.15	7.38	1.70	9.05	8.71	101.99
63	8.86	0.84	2.43	1.42	57.95	15.65	5.51	6.92	99.58
51	14.94	1.58	6.81	.07	43.66	14.88	2.09	9.34	93.37
57	13.33	1.69	8.82	0.35	47.57	6.94	10.30	5.29	94.29
57	14.34	1.18	2.95	0.38	42.74	16.13	4.08	11.20	93.00

TABLE 12. RIVER SEDIMENT DATA FROM PANAMA AND COLOMBIA

a) Panama

Station	River	Date Collected	C.E.C. (me/100g)	Ignition Loss (percent)
18	Setiganti	2-19-67	18	6.30
21	Sabanas ½ hr. above hydro	2-20-67	29	9.19
21	Sabanas-Hydro (shale)	2-20-67	206	4.51
12	Tuira	2-27-67	25	5.09
19	Mogue	3-6-67	31	5.46
14	Uruseca	2- -67	34	6.42
16	Balsas	3-2-67	37	5.63
24	Kunnti	3-4-67	21	4.95
25	Cuadi	3-5-67	13	3.24
20	Sambu	2-24-67	15	3.89
27	Narka	2-2-67	11	2.71
28	Sabalo	3-21-67	25	4.69
22	Congo	3-23-67	13	3.59
11	Chico	2-24-67	18	3.68
10	Tupisa	2-26-67	12	2.82
5	Chucunaque	2-26-67	29	5.72
8	Morti-Hydro	3-16-67	27	4.74
2	Chucunaque-Uala	3-17-67	32	5.99
1	Chucunaque-Nura	3-18-67	Insufficient sample	4.69
9	Membrillo	3-22-67	15	3.16
15	Yape	2-27-67	27	5.00
21	Sabanas	9-7-67	70	----

b) Colombia

Station	River	Date Collected	C.E.C. (me/100g)	Ignition Loss (percent)
58	Salado	3-15-67	33	7.25
57	Quebrada Barrial	3-17-67	39	4.70
67	Perancho	3-18-67	38	6.24
54	Truando	3-16-67	30	7.12
54	Truando	3-16-67	7	8.71
63	Atrato	3-21-67	21	6.92
51	Curiche	3-17-67	34	9.34
57	Nercua-Hotspring	3-17-67	24	5.29
57	Nercua-Above Hotspring	3-17-67	51	11.2

CONTINUED

TABLE 12. RIVER SEDIMENT DATA FROM PANAMA AND COLOMBIA

a) Panama (Seive Analyses)

Station	Dry Wt. (grams)	% Moisture	>1mm (grams)	%	<1 >0.5mm (grams)	%	<0.5 >0.105mm (grams)	%	<0.105 >0.05mm (grams)	%	<0.05mm (grams)	%
18	47.2	5.6	40.0	84.8	3.8	8.1	3.0	6.4	0.2	.42	0.2	0.4
21	49.0	2.0	20.9	42.7	10.1	20.6	14.9	30.4	1.9	3.9	1.2	2.5
21	39.1	21.8	17.0	43.5	9.6	24.6	8.2	21.0	2.7	6.9	1.6	4.1
12	41.9	16.2	1.0	2.4	6.8	16.2	33.6	80.2	0.3	0.7	0.2	0.5
19	49.0	2.0	10.0	20.4	20.9	42.7	17.6	35.9	0.3	.6	0.2	0.4
14	49.0	2.0	0.1	0.2	3.0	6.1	29.3	59.8	13.3	27.1	3.3	6.7
16	49.0	2.0	19.7	40.3	17.1	34.9	11.8	24.0	0.3	0.6	0.1	0.2
24	49.2	1.6	5.9	12.0	25.7	52.2	17.6	35.8	----	----	---	---
25	48.9	2.2	37.3	76.3	7.8	15.9	3.6	7.4	0.1	0.2	0.1	0.2
20	47.1	5.8	40.2	85.4	3.9	8.3	3.0	6.4	----	----	---	---
27	48.8	2.5	6.1	12.5	8.1	16.6	32.3	66.3	2.0	4.1	0.3	0.5
28	42.3	15.5	31.5	74.6	4.7	11.1	5.8	13.7	0.1	0.2	0.1	0.2
22	43.9	12.2	26.3	59.9	4.7	10.7	12.7	29.0	0.1	0.2	0.1	0.2
11	49.3	1.5	----	----	1.0	2.0	47.8	97.0	0.5	1.0	---	---
10	44.8	10.4	1.8	4.0	12.7	28.4	30.2	67.4	0.1	0.1	0.1	0.1
5	49.0	2.0	----	----	----	----	29.0	59.2	15.0	30.6	5.0	10.2
8	32.4	15.2	0.3	.9	1.5	4.6	28.5	88.0	1.3	4.0	0.8	2.5
2	41.5	17.0	31.1	74.9	9.3	22.4	1.0	2.4	0.1	0.1	0.1	0.1
1	46.5	7.0	45.8	98.5	0.5	1.1	0.1	0.2	0.1	0.1	0.1	0.1
9	49.3	1.5	8.4	17.1	14.8	30.1	25.8	52.3	0.3	.6	---	---
15	49.1	1.8	8.2	16.7	15.4	31.4	19.4	39.5	4.1	8.4	2.0	4.7
b) Colombia												
58	39.0	22.0	19.2	49.2	11.0	28.2	7.7	19.7	0.8	2.1	0.3	0.8
57	35.0	30.0	15.6	44.6	10.5	30.0	8.7	24.9	0.1	0.3	0.1	0.3
67	33.0	34.0	6.0	18.2	7.5	22.7	12.6	38.2	5.2	15.8	1.7	5.2
54	45.3	9.5	----	----	1.0	2.2	42.3	93.4	1.8	3.9	0.3	0.6
54	42.0	16.0	----	----	----	----	40.8	97.1	1.1	2.6	0.1	0.3
63	34.2	31.6	----	----	----	----	.4	1.2	28.0	82.0	5.8	16.8
51	33.0	34.0	10.2	30.9	7.6	23.0	13.0	39.4	1.7	5.2	0.5	1.5
57	38.0	24.0	1.9	5.0	5.2	13.7	28.6	75.3	1.7	4.5	0.6	1.6
57	28.0	44.0	0.1	0.4	1.8	6.4	21.8	77.9	3.3	11.8	1.0	3.6

CONTINUED

TABLE 12. CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

River Sediments

(Chemical Analysis on Dry Weight Basis)

		mg/g Na	mg/g K	mg/g Cu	mg/g Mg	mg/g Ca	mg/g Zn	mg/g Sr	mg/g Cr	mg/g Mn	mg/g Fe
Panama Dry I											
HCl Fraction	x̄	0.946	0.599	0.083	6.40	5.74	0.060	0.046	0.028	0.510	27.07
	S.D.	0.854	0.523	0.086	2.92	2.92	0.035	0.028	0.023	0.202	12.90
	S.E.	0.196	0.120	0.019	0.67	0.67	0.008	0.006	0.005	0.046	2.96
	*N	19	19	19	19	19	19	18	19	19	19
HF Fraction	x̄	4.84	1.94	0.084	5.33	5.76	0.021	0.026	0.028	0.227	10.29
	S.D.	2.27	1.26	0.064	7.69	3.36	0.014	0.016	0.026	0.117	7.04
	S.E.	0.52	0.29	0.015	1.76	0.77	0.003	0.004	0.006	0.027	1.62
	*N	19	19	19	19	19	19	19	19	19	19
Colombia Dry I											
HCl Fraction	x̄	1.56	0.561	0.112	8.65	6.37	0.063	0.040	0.052	0.857	32.47
	S.D.	1.19	0.710	0.122	4.01	2.36	0.027	0.025	0.036	0.316	12.75
	S.E.	0.39	0.236	0.041	1.34	0.78	0.009	0.007	0.012	0.105	4.51
	*N	9	9	9	9	9	8	9	9	9	8
HF Fraction	x̄	3.22	1.02	0.106	23.94	9.41	0.044	0.018	0.119	0.713	29.31
	S.D.	2.25	0.80	0.094	23.30	8.06	0.029	0.021	0.061	0.581	20.28
	S.E.	0.75	0.27	0.031	7.76	2.68	0.010	0.007	0.020	0.194	6.76
	*N	9	9	9	9	9	9	9	9	9	9

*Number of Samples.

CONTINUED

TABLE 12. CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

River Sediments

(Chemical Analysis on Dry Weight Basis)

		mg/g Na	mg/g K	mg/g Cu	mg/g Mg	mg/g Ca	mg/g Zn	mg/g Sr	mg/g Cr	mg/g Mn	mg/g Fe
Panama Wet I											
HCl Fraction	$\bar{x}$	0.854	0.714	0.057	8.89	11.38	0.064	0.054	0.028	0.710	37.68
	S.D.	0.634	0.228	0.015	1.92	4.78	0.008	0.037	0.009	0.198	11.03
	S.E.	0.211	0.076	0.005	0.64	1.69	0.003	0.012	0.003	0.066	3.68
	*N	9	9	9	9	8	9	9	9	9	9
HF Fraction	$\bar{x}$	16.55	5.68	0.019	0.62	4.16	0.021	0.008	0.026	0.210	10.81
	S.D.	2.41	0.48	0.009	0.39	2.17	0.006	0.007	0.016	0.074	4.28
	S.E.	0.80	0.16	0.003	0.13	0.72	0.002	0.002	0.005	0.025	1.43
	*N	9	9	9	9	9	9	9	9	9	9

*Number of Samples.

TAXONOMY AND DISTRIBUTION OF FRESHWATER FISHES FROM ROUTE 17 AND 25

South America has, numerically, the greatest freshwater fish fauna of any continental region. At the same time, this fauna is the least known and studied of any continent's. For example, in a recent comprehensive bibliography of the Amazon (Amazonia Bibliografica 1614-1962, Conselho Nacional de Pesquisas, Rio de Janeiro, 1963) the world's largest river system containing the largest number of kinds of fishes of any river, there were only some 100 entries concerning freshwater fishes. The northwestern corner of South America (including both slopes of the Department of Chocó, Colombia) and contiguous eastern Panama (Darien) must be included in the catalog of poorly understood ichthyological regions.

Our meager knowledge of the freshwater fish fauna of the Chocó and northwestern South America in general was organized by Eigenmann (1922), whose work is still the standard source for the area. Later, Myers and Fowler contributed a handful of systematic papers pertinent to the area, and for the Colombian government Miles (e.g., 1947) and Dahl (e.g., 1961) made fairly extensive collections and systematic studies there. For eastern Panama, the work of Meek and Hildebrand (1916) and Breder (1927), summarized by Hildebrand (1938), essentially constitutes our knowledge of this ichthyofauna.

The outstanding importance of the present collections from the interoceanic sea level canal feasibility study to the general ichthyology of this region is quite obvious. In Panama, collection stations included many localities of zoogeographical importance which had never before been sampled, especially rivers outside the Chucunaque-Tuira system. In Colombia, availability of the base camps and the unique facilities of fixed-wing aircraft and helicopters allowed collecting in highly significant but otherwise virtually inaccessible localities. When fully analyzed and reported, these collections will constitute a contribution of primary importance to the zoogeography and ecology of the continent. Of no less significance is the fact that there now exist large collections of fresh, well-preserved specimens of freshwater fishes from the region which should allow much needed critical comparison of Chocó and Darien fishes and these with the faunas of other regions. One of the major unresolved problems encountered in the present study -- how to identify the specimens and what name to apply -- is simply a problem of insufficient systematic study by taxonomists due mainly to lack of large collections of well-preserved materials from distinct areas and habitats of this region. The present collections should go far in changing this situation. The specimens collected will be deposited together in some central museum which has already on hand significant collections of freshwater fishes from this and nearby regions of South and Central America.

With these collections, there now exist -- and only until now -- relatively complete lists of the fishes found in each of the scattered, ecologically diverse riverine areas included in the over-all study. With these collections, we now have some idea of the types of faunas to be found in the distinct types of streams and diverse habitats. We know something of the relative abundance of the different species and the trophic role they plan in their ecosystems -- at least much more than we did before. These matters will be presented and discussed below:

Collections of fishes for identification were made at the majority of stations where water, sediment, fish and invertebrate samples were taken for elemental analysis by the BNW group. In addition, a few other collections were made in localities considered particularly important because of their relevance to distributional problems. All collecting stations are listed and described in Tables 13 and 14. Most collections were made with rotenone (Pronox) and Fintrol, though a few stations were made with small seines or by purchasing fishes from fishermen. Specimens for identification were placed in 10% formalin as quickly as possible after capture; larger specimens were opened on the right side to allow formalin to reach the visceral cavity. Except in some of the collections made in spring 1967, before field techniques had been satisfactorily worked out, all specimens reached the laboratory in excellent condition.

Identifications were made in the Canal Zone, in laboratory space kindly provided by the Middle America Research Unit of the National Institutes of Health. Since no comparative specimens were available, identifications were made mostly on the basis of standard taxonomic and distributional papers. Especially pertinent were Meek and Hildebrand (1916), Breder (1927), Hildebrand (1938) and Loftin (1965) for Panama; and Eigenmann (1922), Miles (1947) and Dahl (1961) for Colombia. However, many of the forms of the two areas are identical or similar, at least to generic level, which facilitated the task. It should be emphasized that the identifications given herein must be considered as provisional. This is necessary not only because of lack of comparative material, incompleteness of the few existing keys, descriptions and lists, or errors and uncertainties; but perhaps even more so to basic systematic uncertanties with the fish faunas. For example, several obvious pairs of congeneric fishes are treated in the published materials as distinct species in Chocó and in Darien.

But comparison, experience and modern systematic concepts strongly suggest that many of these probably represent conspecific pairs, actually differing only subspecifically, if at all. The systematic troubles are greatly compounded when similar comparisons are made between the fishes of this region and other areas of South and Central America.

These nomenclatural difficulties, nonetheless, should be relatively unimportant for the purposes of this present study. To study ecological roles, generic or even family levels are the most significant; and identifications at these levels in this report may be considered firm with very few exceptions -- and these are indicated in the Tables by question marks.

Specimens were sorted and identified for each collection station separately; and each species (or occasionally two species together if they were sufficiently distinct from one another) for each station were separately wrapped in cheese-cloth, labelled, and put in 10% formalin. Later, all specimens were shipped to Battelle-Northwest for storage until final disposition.

Tables 13 - 18 and summarize the findings of this study: Table 25 is of species taken in Panama and Colombia; Tables 13 and 14 are the collecting stations; Table 26 is the distribution of species showing the number of stations at which the species were taken and Table 17 shows the types of species taken from each station.

For these lists, the specific names used by Hildebrand (1938), with some modifications after Miller (1966), for Panama; and specific names used by Dahl (1961), with occasional modifications or corrections, for Colombia; were followed. However, question marks have been employed for the term "unidentified" in particularly dubious situations.

Miller's (1966) order of presentation and nomenclature for higher categories was followed for Panama; the Colombian list is presented within this framework by inserting names not included in Miller's list.

Of particular pertinence to this study, is the division of the freshwater fish fauna into three categories, based on their general relationships of saline tolerance at the family level as proposed by Myers (1938) and modified by Darlington (1957): Primary Freshwater Fishes, generally intolerant of even low salinities; Secondary Freshwater Fishes, somewhat saline tolerant, though basically freshwater forms; and Peripheral Freshwater Fishes, highly saline tolerant or even marine invaders of fresh water. As will be mentioned later, the relative proportion of Primary to Peripheral freshwater fishes may afford a fair indication of the derivation of the fish fauna of a river system and its relationship to the contiguous marine environment, of some importance to radiological studies. Thus the species lists are categorized into these three groupings, ignoring the usual phylogenetic sequence.

In the species list, Table 15 each name is followed by a number (e.g., 5). This number refers to the collecting station where this species was taken. Each species name, likewise, is preceded by a number. This number is also utilized to identify the kinds of fishes taken at each collecting station, Table 15.

In the collecting station list, Tables 13, 14, the following information is given for each station: its identifying number (e.g., BNW-68); whether Atlantic (Atl) or Pacific (Pac) slope; river name or location, date, collectors; identifying field number to be found on the museum specimen tags (e.g., Col-8, or 3-15-67); and information as available on color and turbidity of water, type of bottom, aquatic vegetation, flow, depth and width, approximate elevation, and method of capture. This is followed by numbers indicating the species of fishes taken at each station.

In investigations such as the present feasibility study, it is often useful to estimate the possible degree of biotic influence or exchange on a freshwater system by contiguous marine environments. At least a crude index of this kind may be afforded by the proportion of Primary to Peripheral freshwater fish species in a stream. (Secondary freshwater fishes may be omitted from the ratio, since they are an ambiguous factor in terms of saline tolerance and derivation).

By way of illustration, we may look at the following situations from this study, Table 17.

Of eight stations in the Atrato system, only two contained any Peripheral species, their Primary/Peripheral ratios were 32/2 (Station 58) and 22/1 (Station 72). On the other hand, the Rio Kunti (Station 25) a small stream on the Atlantic coast of Panama had a Primary/Peripheral ratio of 0/10 -- surely highly influenced by the marine environment. Rio Uatí (Station 72) a small stream on the Colombian Coast between the Atrato and the Kuntí showed a ratio of 14/6, suggesting some, but lesser influence from marine conditions.

The Chucunaque-Tuira system in Panama is relatively large and with a sizeable fish fauna, though this fauna was mostly derived at some early period from the Atrato system (see Meek and Hildebrand, 1916, and Loftin, 1965, for discussion). The marine biotic influence on the system from El Real, upstream, can be seen in Table 17. Some ratios are: (1) Station 12, El Real, 4/1; (5) Station 8, Morti, 11/0; (4) Station 9, Membrillo, 10/1; (2) Station 14, Uruseca, 9/2; (3) Station 11, Rio Chico, 15/3.

How "marine" is the Rio Sabana, Station 21, Rio Sambú, Station 20, Rio Congo, Station 22, Station 22, Rio Jaqué Station 35. The ratios: 4/3, 14/3, 6/6, and 2/7 respectively.

This crude "biological index" is suggested here simply as of some possible utility to the larger study. With appropriate refinements, its possibilities for analytic purposes are quite exciting.

Invasion of freshwater streams by essentially marine forms seems to be particularly prevalent in the tropics, for reasons not at all clearly understood. Myers (see Darlington, 1957) has called attention to this situation, designating it as "complementarity": occupation of freshwater niches by essentially marine fishes to the degree that true freshwater fishes do not occupy them. By this concept, it might be considered that the reduced marine biotic influence noted above in the Atrato and Chucunaque-Tuira systems is due more to competition than to lack of ability of certain marine forms to tolerate freshwater conditions. Loftin,on several occasions, has taken genuinely marine fishes at 1,000 - 2,000 foot elevations in Panamanian rivers. In the present investigation, an 8" long flounder (Citharichthys gilberti) was taken in the headwaters of Rio Jaque, Station 35, at an elevation of about 400 feet.

It has been observed elsewhere in Panama that in more or less isolated small rivers and coastal streams the smaller foragers, detritus feeders, insect eaters and scavengers tend to be Primary freshwater fishes, with the role of fish-eating predator largely taken up by Peripheral forms. Even in the Chucunaque-Tuira, predatory eleotrids (Peripheral fishes) (Species Nos. 105-110) are rather abundant, while the large predatory Primary forms common in the Atrato are not nearly so prevalent there.

On the basis of experience and the observations and comments of knowledgeable persons, it seems that, in Panama and the smaller Colombian rivers and probably in the Atrato, little of the energy entering the riverine ecosystems is due to photosynthesis by aquatic vegetation. Most energy, it would seem, enters from the terrestrial environment. Hence, the large proportion of scavengers, detritus feeders and insect eaters among the Primary and even Secondary freshwater fishes. Even the common (in Panama) characin Brycon, a good-sized fish with a mouthful of sharp teeth, strikes avidly at figs and other fruits as these fall into the water from riverside trees. Possibly only some of the armoured catfishes with their numerous, small comb-like teeth derive a major portion of their food from river-produced vegetation, the sparse algal growth occurring on rocks and in the bottom sands and mud

Many of the characins are markedly predatory, or at least vary a scavenging diet with smaller fishes. Roeboides, Cyrtocharax, Piabucina and Brycon fall into this category, while the heavy-bodied, peg-toothed Hoplias is probably a full-time predator of larger fishes. The principal predators among the Primary freshwater fishes, however, are the soft-bodied catfishes, especially members of the family Pimelodidae. The cichlids, the largest group of Secondary freshwater fishes in this region, seem to have much the same role as do centrarchids in North America.

A limited analysis of the gut contents was conducted (Table 18). This data would indicate that for the species examined, the above generalizations and those of Breeder as discussed in the Phase I report, are relevant and would support the contention that these fishes are highly omnivorous.

TABLE 13 COLLECTING STATIONS AND SPECIES TAKEN

PANAMA

BNW-2 (Pac) Rio Chucunaque at Uala, 17 March 67, BNW. (3-17-67). Water clear; gravel and sand bottom; no vegetation; low flow; depth 2-4', width 120'; large pool above a riffle area; frequently dynamited by Indians; elevation 120'; rotenone.

Species: 11, 17, 50, 61

BNW-8 (Pac) Rio Morti at Hydro Station, 16 March 67, BNW. (2-16-67). Water clear, rock and gravel bottom; no vegetation; medium flow; depth 2', width 30'; elevation 100'; rotenone and Fintrol.

Species: 1, 4, 8, 16, 17, 23, 26, 34, 44, 61, 65, 84, 85

BNW-9 (Pac) Rio Membrillo, 22 March 67, BNW. (3-22-67). Water clear; gravel and sand bottom, no vegetation; low flow; depth 2-3', width 60' main channel; 50' side channel where we fished; elevation 100'; rotenone and Fintrol.

Species: 1, 4, 8, 16, 17, 23, 26, 34, 39, 43, 44, 50, 51, 54, 56, 61, 65, 66, 74, 75, 78, 81, 83, 84, 109

BNW-11 (Pac) Rio Chico, 10-15 miles above Yaviza, 25 Feb. 67, BNW. (2-25-67). Water clear; gravel and sand bottom; no vegetation; low flow; depth 3', width to 200'; elevation 50'; rotenone.

Species: 1, 4, 18, 20, 27, 34, 38, 44, 51, 54, 59, 65, 66, 67, 75, 78, 84, 109, 110, 112

BNW-12 (Pac) Rio Tuira at El Real, 24-27 Feb. 67, BNW (2-24-27-67). Water turbid; good flow; depth? width, elevation 50'; purchased caught on line.

Species: 27, 35, 58, 78, 105

BNW-13 (Pac) Rio Pirre, 3-5 miles above El Real, 24-27 Feb. 67, BNW. (2-24-27-67). Water clear; gravel bottom; no vegetation; medium flow; depth 2½', width to 40'; elevation 50'; purchased caught on line.

Species: 4, 16, 18, 20, 22, 23, 27, 44, 46, 48, 54, 58, 59, 63, 65, 75, 78, 83, 109, 110,

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TABLE 13 COLLECTION STATIONS AND SPECIES TAKEN

BNW-14 (Pac) Rio Uruseca, 2 miles above El Real, 26 Feb. 67, BNW. (2-26-67). Water clear; mud bottom; no vegetation; low flow; depth 2' width 10' elevation 50'; rotenone.

Species: 4, 5, 11, 16, 18, 20, 23, 38, 78, 83, 84, 85, 109, 112

BNW-15 (Pac) Rio Yape at Yape, 27 Feb. 67, BNW. (2-27-67). Water clear; gravel and sand bottom; no vegetation; low flow; depth 2' width to 50'; elevation 3'; rotenone.

Species: 63, 71, 75

BNW-16 (Pac) Rio Balsas above Tucuti, 3 March 67, BNW. (3-3-67). Water clear; gravel and sand bottom,cobblestone; good flow; no vegetation; depth 1-3' width 50'; elevation 50'; rotenone.

Species: 4, 18, 20, 27, 50, 52, 61, 63, 65, 75, 84, 85, 109

BNW-19 (Pac) Rio Mogue, 5 miles upstream, 6 March 67, BNW. (3-6-67). Water clear; gravel and sand bottom; slow flow; no vegetation; depth 1' width 10'; elevation 30' ; rotenone.

Species: 11, 59, 75, 84, 96, 98, 100, 109, 112, 116, 117, 118, 122

BNW-20 (Pac) Rio Sambu, 25 March 67, BNW. (3-25-67). Fished Quebrada La Pulnalada; within ¼ mile of the Rio Sambu, the Quebrada was clear; gravel and sand and mud bottom; no vegetation; low flow; depth 2-6',width 25'; elevation 80'; rotenone.

Species: 6, 11, 16, 20, 23, 27, 34, 38, 51, 59, 61, 65, 66, 76, 76, 81, 84, 87, 109, 110, 112

BNW-21 (Pac) Rio Sabanas, 3 miles above Santa Fe, 20 March 67, BNW. (3-20-67). Water clear; gravel bottom; no vegetation; no flow; depth 2',width to 30'; elevation 50'; rotenone.

Species: 18, 23, 54, 75, 78, 95, 106, 109

BNW-22 (Pac) Rio Congo, 24 March 67, BNW. (3-24-67). Water clear; rock and gravel bottom; no vegetation; depth 18" -2'; some encrusting algae; width 20'; elevation 80'; rotenone.

Species: 6, 9, 23, 27, 50, 54, 56, 81, 106, 109, 110, 112, 113

TABLE 13 COLLECTION STATIONS AND SPECIES TAKEN

BNW-23 (Pac) Quebrada Coho, tributary of Rio Congo, 8 March 67, BNW. (3-8-67). Water clear; gravel and sand bottom; no vegetation; low flow; depth 2',width to 20' ; elevation 50'; rotenone.

Species: 54, 78, 90, 104, 106, 109, 112, 121, 122

BNW-24 (Atl) Rio Kunnti, near Caledonia Bay, 3 miles upstream, 4 March, 67, BNW. (3-4-67). Water clear; gravel and sand bottom; no vegetation; low flow depth 2',width to 10' ; elevation 10-20' ; rotenone.

Species: 76, 90, 93, 94, 101, 102, 107, 108, 111, 115, 122

BNW-25 (Atl) Rio Cuadi, near Sasardi, 5-19 March 67, BNW. (3-5-67). Water clear; mud and sand bottom; no vegetation; low flow; depth 6', width to 50'; elevation 20';rotenone and Fintrol.

Species: 6, 8, 12, 27, 28, 38, 51, 54, 61, 76, 78-80, 88, 101, 102, 107, 108, 111, 114, 122

BNW-27 (Atl) Rio Narka, 5 miles upstream, 2-30 March 67, BNW. (3-2-67). Water clear; sand and mud bottom; no vegetation; low flow; depth to 4', width to 30'; elevation 20-30';rotenone and Fintrol.

Species: 8, 12, 38, 50, 76, 89, 91, 93, 94, 97, 99, 101, 102, 107, 108, 111, 115

BNW-28 (Pac) Rio Saba?o, tributary of the upper Rio Bayano system, 1 mile above Naragandi, 21 March 67, BNW. (3-21-67). Water clear; rock and gravel bottom; no vegetation; low flow; depth 18" to 6' in pool; width 30'; elevation 250';rotenone.

Species: 61, 81, 85, 87

BNW-35 (Pac) Rio Jaque, upper tributary of, 11 Feb. 68, Loftin and Dean (Col-13). Water clear; bottom rock, gravel; sand; no vegetation; flow fair; depth to 3', width to 20'; about 400' elevation'; rotenone.

Species: 6, 8, 76, 95, 102, 109, 110, 112, 113, 116, 120

TABLE 14 COLLECTION STATIONS AND SPECIES TAKEN

COLOMBIA

BNW-51 (Pac) Rio Curiche, 2 small creeks about 5 min. helicopter flight from Camp Curiche, 1 Sep. 67, Loftin and Fowler (Col-08). One creek clear, other opaque and muddy; bottom sand and mud with detritus in still creek; no vegetation; fair to no flow; depth to 2', width to 10'; less than 100' ; elevation.; 10' seine.

Species: 10, 12, 24, 35, 109, 110

BNW-52 (Pac) Rio Jurado, creek of, close to Panama border if not past it, 31 Aug. 67, Loftin (Col-07). Water clear; bottom muddy, sand, rock; no vegetation; good flow; depth to 4', width to 10'; about 250' elevation; rotenone.

Species: 4, 10, 24, 25, 31, 37, 41, 79, 81, 84, 102, 110, 112, 113, 114

BNW-54 (Atl) Rio Truando, 2 small creeks just below rapids upstream from Teresita, 30 Aug. 67, Loftin (Col-05). Water gray, turbid; bottom sandy clay, rock, fallen logs; no vegetation; some flow; depth to 4', width to 15'; about 300'; elevation 15' seine.

Species: 4, 14, 24, 25, 31

BNW-56 (Atl) Rio Nercua, creek into upper river, 28 Aug. 67, Loftin and Fowler (Col-02). Water clear; bottom sand, large rock; some "moss" on rocks; good flow; depth to 4', width to 10'; about 300' elevation; rotenone.

Species: 2, 10, 12, 13, 17, 24, 25, 33, 34, 45, 51, 55, 61, 64, 69, 75, 79, 82, 84

BNW-57 (Atl) Quebrada Barrial, tributary of Rio Nercua, 17 March 67, BNW. (3-17-67). Water clear; bottom gravel and sand; no vegetation; fair flow; depth to 3'; width to 10'; elevation 150' rotenone.

Species: 10, 12, 13, 17, 22, 24, 25, 33, 37, 45, 55, 61, 72, 75, 84

TABLE 14 COLLECTION AND SPECIES TAKEN

BNW-58a(Atl) Rio Salado, 4 miles above confluence with Rio Truando, 15 March 67, BNW. (3-15-67). Water clear; bottom gravel and sand, no vegetation; flow fair; depth to 3' width to 20' - elevation 180' ; rotenone.

.BNW-58b(Atl) Rio Salado, about ½ mile above confluence with Rio Truando, 27 Aug. 67, Loftin (Col-01). Water high from flooding; charcos deep; river down about 15' from flood of previous day; water clear to turbid, white to reddish; bottom sand and rock, but covered with clay silt; no vegetation; flow good; depth to 10' in charcos, width to 20'; about 200' elevation ; rotenone.

BNW-58c(Atl) Rio Salado, about 1 mile above confluence with Rio Truando; water clear; bottom gravel, rock, clay; no vegetation; flow fair; depth to 4', width to 20'; about 200' elevation; rotenone.

Species: 2, 3, 4, 5-10, 13, 14, 17, 18, 20, 21, 24, 25, 29, 30, 31, 32, 37, 39, 42, 51, 54, 60, 61, 62, 64, 68, 69, 70, 75, 77, 79, 80, 84, 86, 92, 119

BNW-63a(Atl) Rio Atrato near town of Rio Sucio, 20-21 March 67, BNW. (3-20-21-67).

BNW-63b(Atl) Rio Atrato at town of Rio Sucio, 9 Feb. 68, Loftin (Col-10). Purchased from hook-and-line fishermen; all but Hoplias (#25) taken at town docks; there about 3' deep; clay banks; water brown and turbid; no vegetation; less than 100' elevation.

Species: 5, 18, 21, 22, 27, 29, 45, 47, 48, 54, 62, 72, 82

BNW-64 (Atl) Rio Atrato above Puerto Libre, 29 Aug. 67, Loftin, Dean and Fowler (Col-04). Purchased from local fishermen; caught on trot lines in main river; here about ½ mile wide; water reddish and turbid; less than 100' elevation.

Species: 45, 48, 52, 53

BNW-68 (Atl) Rio Cuti, small river near lower reach of Rio Atrato, 29 Aug. 67, Loftin, Dean and Fowler (Col-03). Water reddish, turbid; bottom sandy mud; logs and detritus; no vegetation; flow fair; depth to 5', width to 15'; less than 100' elevation; 10' seine.

Species: 4, 10, 12, 13, 14, 24, 31, 62, 64, 72, 75

TABLE 14 COLLECTION AND SPECIES TAKEN

BNW-69 (Atl) Rio Uati, near Acandi, 9 Feb. 68, Loftin and Dean (Col-11). Water clear; bottom sand, gravel, rock, some clay; no vegetation; flow fair; depth to 6', width to 20'; less than 100' elevation; rotenone.

Species: 4, 7, 10, 12, 14, 17, 24, 27, 31, 37, 51, 57, 61, 72, 73, 76, 80, 86, 97, 101, 102, 103, 111, 114

BNW-71 (Pac) Rio Parado, creek of, about 10 min. helicopter flight from coast, 31 Aug. 67, Loftin (Col-06). Water clear; bottom sandy mud, sand, rock; good flow; no vegetation; depth to 4', width to 15'; about 150' elevation; rotenone.

Species: 10, 12, 24, 37, 39, 72, 74, 75, 81, 84, 95, 100, 102, 109, 110, 112, 113, 120

BNW-72 (Atl) Rio Pavarando, large tributary of Rio Salaqui, 10 Feb. 68, Loftin and Dean (Col-12). Water clear; bottom rock, gravel, sand; no vegetation; flow fair; depth to 4', width to 30'; about 400' elevation; rotenone.

Species: 3, 4, 5, 7, 13, 14, 17, 21, 24, 29, 30, 31, 32, 36, 39, 45, 49, 51, 61, 64, 68, 71, 77, 84, 86, 92

TABLE 15. SPECIES TAKEN AT PANAMA (P) AND COLOMBIA (C) STATIONS

PRIMARY FRESHWATER FISHES

CHARACIDAE

1. Apareidon dariensis: (P)-8,9,11
2. ?Apareidon sp.: (C)-56,58
3. Astyanax atratoensis: (C)-58,72
4. Astyanax fasciatus: (P)-8,9,11,13,14,16; (C)-52,54,58,68,69,72
5. Astyanax orthodus: (C)-58,63,72
6. Astyanax ruberrimus: (P)-9,14,20,22,25,35
7. Astyanas sp.: (c)-69,72
8. Brycon argenteus: (P)-8,9,25,27,35
9. Brycon striatulus: (P)-22
10. Brycon spp.?: (C)-51,52,56,57,58,68,69,72
11. Bryconamericus emperador: (P)-2,14,19,20
12. Bryconamericus sp.: (P)-25,27; (C)-51,56,57,68,69,71
13. Characidium fasciatum: (C)-56,57,58,68,72
14. Characidium marshi: (P)-9
15. Cheirodon insignis or 31: (C)-52,54,58,68,69,72
16. Compsura gorgonae or 33: (P)-8,9,13,14,20
17. Creagrutus affinis: (P)-2,8,9; (C)-56,57,58,69,72
18. Ctenolucius beani: (P)-9,11,13,14,16,21; (c)-58,63
19. Curimata atratoensis: (C)-58,72
20. Curimata magdalenae: (P)-9,11,13,14,16,20; (C)-58
21. Cyrtocharax atratoensis: (C)-58,63,72
22. Gasteropelecus maculatus: (P)-9,13; (C)-57,63

TABLE 15. SPECIES TAKEN AT PANAMA (P) AND COLOMBIA (C) STATIONS

CHARACIDAE (Continued)

23. *Gephyrocharax atricaudatus*: (P)-8,13,14,20,21,22

24. *Gephyrocharax chocoensis*: (C)-51,52,54,56,57,58,68,69,71,72

25. *Hemibrycon carrilloi*: (C)-52,54,56,57,58

26. *Hemibrycon dariensis*: (P)-8,9,14

27. *Hoplias malabaricus*: (P)-11,12,13,16,20,22,25; (C)-63,69

28. *Hyphessobrycon panamensis*: (P)-25

29. *Leporinus muyscorum*: (C)-58,63,72

30. *Leporinus striatus*: (C)-58,72

31. *Odontostilbe hastata* or 15: (C)-52,54,58,68,69,72

32. *Parodon suborbitalis*: (C)-56,57,58,72

33. *Pseudocheirodon affinis* or 16: (P)-8,9,13,14,20

34. *Phanagoniates macrolepis*: (P)-8,9,11,20; (C)-56

35. *Piabucina festae*: (P)-12; (C)-51

36. *Prochilodus magdalanae*: (C)-58,72

37. *Roeboides dayi*: (C)-52,57,59,69,71

38. *Roeboides occidentalis*: (P)-9,11,14,20,22,25,27

GYNMOTIDAE

39. *Apteronotus rostratus*: (P)-9; (C)-58,71,72

40. *Eigenmannia virescens*: (P)-9,20; (C)-56,57,72

41. *Gymnotus carapo*: (C)-52

42. *Hypopomus brevirostris*: (C)-58

43. *Hypopomus occidentalis*: (P)-9

44. *Sternopygus dariensis*: (P)-8,9,11,13

45. *Sternopygus macrurus*: (C)-56,57,63,64,72

TABLE 15 . SPECIES TAKEN AT PANAMA (P) AND COLOMBIA (C) STATIONS

AUCHENIPTERIDAE

46. *Trachycorystes amblops*: (P)-13

47. *Trachycorystes fisheri*: (C)-63

AGENEIOSIDAE

48. *Ageneiosus caucanus*: (P)-13; (C)-63,64

PIMELODIDAE

49. *Cetopsorhamdia* sp.: (C)-58,72

50. *Imparales* sp.: (P)-2,9,16,22,27

51. *Pimelodella chagresi*: (P)-9,11,20,21,25; (C)-56,58,69,72

52. *Pimelodus clarias*: (P)-16; (C)-64

53. *Pseudopimelodus bufonius*: (C)-64

54. *Rhamdia wagneri*: (P)-9,11,13,21,22,23,25; (C)-58,63

CETOPSIDAE

55. *Pseudocetopsis amphiloxa*: (C)-56,57

56. *Pygidium striatum*: (P)-9,22

57. *Pygidium* sp.: (C)-69

CALLICHTHYIDAE

58. *Hoplosternum thoracatum*: (P)-12,13

LORICARIDAE

59. *Ancistrus spinosus*: (P)-11,13,19,20

60. *Astroblepus rengifoi*: (C)-58

TABLE 15. SPECIES TAKEN AT PANAMA (P) AND COLOMBIA (C) STATIONS

LORICARIDAE (Continued)

61. Chaetostoma fischeri: (P)-2,8,9,16,20,25,28; (C)-56,57,58,69,72

62. Cheirododus hondae: (C)-58,63,68

63. Hypostomus plecostomus: (P)-13,15,16

64. Lasiancistrus mayoloi: (C)-56,58,68,72

65. Lasiancistrus planiceps: (P)-8,9,11,13,16,20

66. Loricaria altipinnis: (P)-9,11,20

67. Loricaria filamentosa: (P)-11

68. Loricaria gymnogaster ?: (C)-58,72

69. Loricaria magdalenae ?: (C)-56,58

70. Loricaria seminuda ?: (C)-58

71. Loricaria variegata: (P)-15; (C)-72

72. Loricaria spp. ?: (C)-57,63,68,69

73. ? Pseudoancistrus sp.: (C)-69

74. Sturisoma citurense: (P)-9; (C)-71

75. Sturisoma panamense: (P)-9

SECONDARY FRESHWATER FISHES

POECILIIDAE

76. Unidentified poeciliids: (P)-20,24,25,27,35; (C)-69

POTAMOTRYGONIDAE

77. Potamotryogon magdalenae: (C)-58,72

CONTINUED

TABLE 15. SPECIES TAKEN AT PANAMA (P) AND COLOMBIA (C) STATIONS

CICHLIDAE

78. *Aequidens coeruleopunctatus*: (P)-9,11,12,13,14,21,23,25

79. *Aequidens latifrons*: (C)-52,56,58

80. *Cichlasoma atromaculatum*: (P)-25; (C)-58,69

81. *Cichlasoma calobrense*: (P)-9,20,22,28; (C)-52,71

82. *Cichlasoma kraussi*: (C)-56,63

83. *Cichlasoma tuyrense*: (P)-9,13,14

84. *Cichlasoma umbriferum*: (P)-8,14,16,28

85. *Geophagus crassilabris*: (P)-8,14,16,28

86. *Geophagus pellegrini*: (C)-58,69,72

87. *Neetroplus panamensis*: (P)-20,28

SYNBRANCHIDAE

88. *Synbranchus marmoratus*: (P)-25

ENGRAULIDAE

89. *Anchoa* sp.: (P)-27

OPHICHTHIDAE

90. Unidentified eels: (P)-23,24

ANGUILLIDAE

91. *Anguilla rostrata*: (P)-27

BELONIDAE

92. *Tylosurus fluviatilis*: (C)-58,72

CONTINUED

TABLE 15. SPECIES TAKEN AT PANAMA (P) AND COLOMBIA (C) STATIONS

SYNGNATHIDAE

93. *Oostethus lineatus*: (P)-24,27

94. *Pseudophallus mindii*: (P)-24,27

95. *Syngnathus elcapitanensis*: (P)-21,35; (C)-71

CENTROPOMIDAE

96. *Centropomus* sp.: (P)-19

CARANGIDAE

97. Unidentified carangid: (P)-27; (C)-69

GERRIDAE

98. *Diapterus* sp.: (P)-19

99. *Eucinostomus* sp.: (P)-27

POMADASYIDAE

100. *Pomadasys bayanus*: (P)-19; (C)-71

101. *Pomadasys crocro*: (P)-24,25,27; (C)-69

MUGILIDAE

102. *Agonostomus monticola*: (P)-24,25,27,35; (C)-52,69,71

103. *Joturus pichardi*: (C)-69

104. *Mugil* sp.: (P)-23

CONTINUED

TABLE 15. SPECIES TAKEN AT PANAMA (P) AND COLOMBIA (C) STATIONS

ELEOTRIDAE

105. *Dormitator latifrons*: (P)-12

106. *Eleotris picta*: (P)-21,22,23

107. *Eleotris pisonis*: (P)-24,25,27

108. *Gobiomorus dormitor*: (P)-24,25,27

109. *Gobiomorus maculatus*: (P)-9,11,13,14,16,19,20,21,22,23,35; (C)-51,52,71

110. *Hemieleotris latifasciatus*: (P)-11,13,20,22,35; (C)-51,52,71

GOBIDAE

111. *Awaous tajasica*: (P)-24,25,27; (C)-69

112. *Awaous transandeanus*: (P)-11,14,19,20,22,23,35; (C)-52,71

113. *Sicydium salvini*: (P)-22,35; (C)-52,71

114. *Sicydium* sp.: (P)-25; (C)-69

115. Unidentified gobies: (P)-24,27

BOTHIDAE

116. *Citharichthys gilberti*: (P)-19,35

SOLEIDAE

117. *Trinectes fluviatilis*: (P)-19

118. *Trinectes fonsecensis*: (P)-19

BATRACHOIDIDAE

119. *Thalassophryne quadrizonatus*: (C)-58

CONTINUED

TABLE 15. SPECIES TAKEN AT PANAMA (P) AND COLOMBIA (C) STATIONS

GOBIESOCIDAE

120. *Gobiesox potamius* ?: (P)-35; (C)-71

TETRAODONTIDAE

121. *Sphoeroides annulatus*: (P)-23

OTHERS

122. Unidentified saltwater fishes: (P)-19,23,24,25

TABLE 16.. DISTRIBUTION OF SPECIES: NUMBER OF STATIONS AT WHICH THAT SPECIES WAS TAKEN.

Species Number	Panama	Colombia	Total
1	3	0	3
2	0	2	2
3	0	2	2
4	6	6	12
5	0	3	3
6	6	0	6
7	0	2	2
8	5	0	5
9	1	0	1
10	0	8	8
11	4	0	4
12	2	6	8
13	0	5	5
14	1	0	1
15	0	6	6
16	5	0	5
17	3	5	8
18	6	2	8
19	0	2	2
20	6	1	7
21	0	3	0
22	2	2	4
23	6	0	6
24	0	10	10
25	0	5	5
26	3	0	3
27	7	2	9
28	1	0	1
29	0	3	3
30	0	2	2
31	0	6	6
32	0	4	4
33	5	0	5
34	4	1	5
35	1	1	2
36	0	2	2
37	0	5	5
38	7	0	7
39	1	3	4
40	2	3	5
41	0	1	1
42	0	1	1
43	1	0	1

CONTINUED

TABLE 16. DISTRIBUTION OF SPECIES: NUMBER OF STATIONS AT WHICH THAT SPECIES WAS TAKEN.

Species Number	Panama	Colombia	Total
44	4	0	4
45	0	5	5
46	1	0	1
47	0	1	1
48	1	2	3
49	0	2	2
50	5	0	5
51	5	4	9
52	1	1	2
53	0	1	1
54	7	2	9
55	0	2	2
56	2	0	2
57	0	1	1
58	2	0	2
59	4	0	4
60	0	1	1
61	7	5	12
62	0	3	3
63	3	0	3
64	0	4	4
65	6	0	6
66	3	0	3
67	1	0	1
68	0	2	2
69	0	2	2
70	0	1	1
71	1	1	2
72	0	4	4
73	0	1	1
74	1	1	2
75	8	5	13
76	5	1	6
77	0	2	2
78	8	0	0
79	0	3	3
80	1	2	3
81	4	2	6
82	0	2	2
83	0	3	3
84	7	6	13
85	4	0	0

CONTINUED

TABLE 16. DISTRIBUTION OF SPECIES: NUMBER OF STATIONS AT WHICH THAT SPECIES WAS TAKEN.

Species Number	Panama	Colombia	Total
86	0	3	3
87	2	0	2
88	1	0	1
89	1	0	1
90	2	0	2
91	1	0	1
92	0	2	2
93	2	0	2
94	2	0	2
95	2	1	3
96	1	0	1
97	1	1	2
98	1	0	1
99	1	0	1
100	1	1	2
101	3	1	4
102	4	3	7
103	0	1	1
104	1	0	1
105	1	0	1
106	3	0	3
107	3	0	3
108	3	0	3
109	11	3	14
110	5	3	8
111	3	1	4
112	7	2	9
113	2	2	4
114	1	1	2
115	2	0	2
116	2	0	2
117	1	0	1
118	1	0	1
119	0	1	1
120	1	1	2
121	1	0	1
122	4	0	4

46 - Panama

41 - Colombia

35 - Common to both

TABLE 17. RELATIVE PROPORTIONS OF PRIMARY, SECONDARY AND PERIPHERAL FRESHWATER FISHES.

Station Number	Total No. of Species Collected	Primary	Secondary	Peripheral	Primary/Peripheral
Panama					
2	4	4	0	0	4-0
8	13	11	2	0	11-0
9	25	20	4	1	20-1
11	20	15	2	3	15-3
12	5	3	1	1	3-1
13	20	16	2	2	16-2
14	15	9	4	2	9-2
15	3	3	0	0	3-0
16	13	10	2	1	10-1
19	13	3	1	9	3-9
20	21	14	4	3	14-3
21	8	4	1	3	4-3
22	13	6	1	6	6-6
23	9	1	1	7	1-7
24	11	0	1	10	0-10
25	20	9	4	7	9-7
27	17	4	1	12	4-12
28	4	1	2	1	1-1
35	10	2	1	7	2-7
Colombia					
51	6	4	0	2	4-2
52	16	8	3	5	8-5
54	5	5	0	0	5-0
56	19	16	3	0	16-0
57	15	14	1	0	14-0
58	39	32	5	2	32-2
63	13	12	1	0	12-0
64	4	4	0	0	4-0
68	11	11	0	0	11-0
69	24	15	3	6	15-6
71	18	8	2	8	8-8
72	26	22	3	1	22-1

TABLE 18 GUT CONTENTS OF TWO OF THE MAJOR FOOD FISHES IN PANAMA AND COLOMBIA.

GUT CONTENT OF SABALETA (*Brycon* sp.)

Rio Cuadi, Panama (Station 25) — Collection 3/19/67

Fish Number	Fork Length	Net Wt.	Net Wt. of Gut Content		Occurrance—% by Vol.
1	21.5 cm	183.9 g	1.85 g	Chitin, unidentifiable tissue	20
				associated with green leaves (pinnate venation)	80
2	23.0	269.8	6.90	Crustacean, reptile (probably	50
				a leg of a turtle)	50
3	16.0	112.2	2.00	Green leaves (same as in Fish #1)	95
				Unidentifiable tissue	5
4	24.0	246.3	.20	Chitin associated with highly decomposed tissue	100
5	20.5	168.8	5.83	Green leaves (same as in Fish #1 and #3)	1
				1 fish-genus *Hemibrycon*	10
				1 spider	89

CONTINUED

TABLE 18 GUT CONTENT OF BOCACHICO (*Prochilodus agdalenae*)

Rio Salado, Colombia (Station 58) Collected 3/15/67

Fish Number	Fork Length	Net Wt.	Net Wt. of Gut Content		Occurrance % by Vol.
1	19.0 cm	222.9 g	0		
2	20.5 cm	190.6 g	.1 g	Fine gravel	100
3	22.0 cm	243.0 g	0		
4	20.0 cm	203.9 g	.2	Unidentifiable debris	100
5	23.5 cm	228.3 g	0		

CHEMICAL COMPOSITION OF AQUATIC ORGANISMS

In order to meet the objective of the study within the limited time period and funds allocated, it was decided to concentrate on geographical and topographical coverage of the watersheds of Route 17 and 25 recognizing that this would result in some loss of detail and precision. The major sampling period for organisms was in Dry season I. Stations were selected in the absence of any reliable water data, on the basis of population centers and ethnic areas. In order to achieve this broad survey, certain aspects had to be sacrificed. Among these were detailed studies of particular areas and the inherent variability in amount of trace elements in samples collected at the same time and area. As Lowman (1966) points out in a review of trace element variability, such data is necessary for detailed statistical comparisons. Such detailed studies that have been made in the marine environment with relative constant concentrations in the medium indicate order of magnitude variations within species from one area. In the freshwater ecosystem in general, where ranges of trace elements can extend over two orders of magnitude variability between the same or related species from different water systems would be expected. However, all of the data presented for biological samples is a composite of many individuals except in the case of elements determined by activation analysis.

Fish samples were analyzed as muscle, bone, skin-head-fin and as whole fish. The muscle samples were taken as fillets, and would therefore, contain some bone. Muscle tissues of shrimp and crayfish were analyzed as was the whole organism. For the snails, soft tissues was removed from the shell for analysis. While only muscle tissue was analyzed from cayman and turtle.

The wet, dry and ash weights for standard samples were taken and the ratios calculated. Table 19 . Relative proportions of muscle, bone and rest for three common food fish are given in Table 20 .

Some problems were encountered in the field on taxonomy, but samples were retained for positive identification (Section VII). Those species of fish analyzed are given in Table 21 with the common name, and referenced to the distribution list.

The detailed data are presented in Appendix I by route, date and season, river location, and common name.

Since the objective is to provide data on the degree of concentration of the stable elements in order that the accumulation of radionuclides could be predicted on a broad base, and to investigate whether these tropical freshwater systems possessed unique features, detailed analyses of relationships of elements station by station was not attempted.

The mean values ($\bar{x}$) for each element for both routes, together with standard deviation (S.D.) and standard error (S.E.) were calculated for fish by tissue and by sampling season, Tables 22 - 27 . The data for macroinvertebrates and reptiles collected in Dry season I are shown in Table 25

The mean values obtained in this study are comparable with published data. The most consistent of the major elements were potassium and magnesium in fish muscle and bone. Sodium and calcium, however, showed large variations, which were not compatible with the concentration of the element in the sampling station waters. Whilst published data indicates that within a species, the calcium concentrations are relatively constant (Templeton and Brown 1964) interspecies variation can be considerable. Viswanathan et al (1966) indicates a range of 0.056 - 12.6 mg/g for calcium in the muscle tissues of 16 species of tropical freshwater fish in India, which can be compared with a mean value in this study of 0.90 ± 0.73 mg/g. Copper values in the muscle of 16 species ranged from 0.13 ± 0.15 μg/g in this study. The iron concentrations in muscle were comparable (Table 26).

For comparative purposes, the tissues of five Cichlid fish (A. portalengrensis), which had been maintained in Columbia River water at Hanford for over a year were analyzed. Table 27 . Na, Zn, Sr, Mn and Fe were all less than the mean values obtained in the study though not more than a factor of three.

Of interest are the relatively high values of mercury determined by activation analysis in all samples from Panama and Colombia.

Thirty samples of fish, reptiles and macroinvertebrates were analyzed for carbon, hydrogen and nitrogen. The hydrogen analyses were made on dry tissue and was considered as organically bound hydrogen. The difference between wet and dry weight was considered as unbound hydrogen in the form of water. There was no significant difference between the obtained vlaues of C, H and N for all dry muscle tissues and these were comparable with published values (Vinogradov 1953). A mean value of 8.74 grams of hydrogen per 100 grams wet tissue was calculated, 14.4% of which can be considered in the organically bound state.

TABLE 19. DRY/WET, ASH/WET AND ASH/DRY RATIOS FOR BIOLOGICAL SAMPLES

	Dry/Wet			Ash/Wet			Ash/Dry		
	x̄	S.D.	N*	x̄	S.D.	N*	x̄	S.D.	N*
Fish									
Muscle	.213	.020	40	.015	.016	22	.070	.066	22
Bone	.635	.097	40	.304	.066	22	.485	.068	22
Skin-Head-Fin	.398	.092	40	.102	.078	22	.239	.133	22
Whole Fish	.280	.023	5	.066	.101	4	.232	.028	4
Crustaceans (Shrimp and Crayfish)									
Muscle	.243	.006	4	.011	.003	2	.047	.010	2
Whole Organism	.263	.039	3	.007	.050	2	.177	.029	2
Reptiles (Cayman and Turtle)									
Muscle	.202	.016	4	.004	.002	2	.018	.006	2
Gastropod Snail									
Muscle	.195	.003	2	.011	---	1	.056	---	1

*Number of samples

TABLE 20 STANDARD FISH FOR SEA LEVEL CANAL STUDIES

Genus	Location	Length	Total Net Weight	Net Weight Muscle	Muscle %	Net Weight Bone	Bone %	Net Weight Remainder	Remainder %
Hoplias	Rio Balsas	24 cm	119.10	58.770	49	7.870	7	52.456	44
	3-3-67	20 cm	103.75	47.430	46	6.869	7	49.451	47
Chichlasoma	Rio Chico	19 cm	71.25	28.221	40	5.704	8	37.329	52
	3-8-67	28 cm	244.10	93.163	38	20.067	8	130.870	54
Prochilodus	Rio Salado	28 cm	210.70	82.677	39	12.897	6	113.216	55
	3-10-67	26 cm	191.10	76.625	40	11.933	6	102.538	54
"Standard Fish"	Mean				42		7		51

TABLE 21. COMMON AND SCIENTIFIC NAMES OF FISH ANALYZED FOR STABLE ELEMENTS

Common Name	Family Name	Scientific Name (species number)
Cichlid	CICHLIDAE	Aequidens portalegrensis A. caeruleopunctatus (78) A. latifrons (79)
Mojarra	CHARACIDAE	Aequidens latifrons (79) A. caeruleopunctatus (78) Cichlasoma atromaculatum (80)
Aguja	CHARACIDAE	Etenolucius beani (18)
Bocochico	CHARACIDAE	Prochilodus magdalenae (36)
Dientin Pez Perro	CHARACIDAE	Hoplias malabaricus (27) Leporinus muyscorum (29)
Sardinas	CHARACIDAE	Astyanax atratoensis (3) Astryanax fasciatus (4) Bryconamericus emperador (11)
Sabaleta	CHARACIDAE	Brycon (8-9)
Comenata	PIMELODIDAE	All Genera in this Family (49-54)
Congo	PIMELODIDAE	Rhamdia wagneri (54)
Doncella	AGENEIOSIDAE	Ageneiosus caucanus (48)
Machana	GYNMOTIDAE	Sternopygus sp. (44-45)
Guacoco	LORICARIIDAE	Hypostomus plecostomus (63)
Lisa	MUGILIDAE	Agonostomus monticola (102)
Parbo	ELEOTRIDAE	Dormitator latiforns (105)

TABLE 22. CONCENTRATION OF ELEMENTS IN SAMPLES
FROM PANAMA AND COLOMBIA

Fish-Muscle

		(Chemical Analysis Based on Wet Weight)										(Dry Weight)		
		mg/g	mg/g	μg/g	mg/g	mg/g	μg/g	μg/g	μg/g	μg/g	μg/g	%	%	%
		Na	K	Cu	Mg	Ca	Zn	Sr	Cr	Mn	Fe	C	H	N
Dry I	x̄	2.16	2.89	.395	.219	.768	12.69	1.64	--	1.40	9.72	47.35	6.90	13.76
	S.D.	4.38	.77	.178	.163	.820	11.64	1.47	--	1.54	6.95	2.87	.43	.93
	S.E.	.94	.16	.038	.035	.175	2.60	.31	--	.33	1.48	.68	.10	.22
	*N	22	22	22	22	22	22	22	--	22	22	18	18	18
Wet I	x̄	.82	3.07	.388	.252	1.004	4.73	.50	.251	.38	10.73	48.48	6.92	15.15
	S.D.	.27	.30	.065	.020	.367	1.80	.42	.154	.17	4.61	.82	.10	.33
	S.E.	.12	.14	.029	.009	.164	.80	.19	.069	.08	2.06	.41	.05	.17
	*N	5	5	5	5	5	5	5	5	5	5	4	4	4
Dry II	x̄	.99	3.93	.293	.304	1.270	6.00	1.11	.600	1.33	19.97	--	--	--
	S.D.	.70	.91	.228	.024	.478	2.08	1.23	.560	1.76	13.94	--	--	--
	S.E.	.27	.34	.083	.009	.180	.78	.47	.212	.66	5.27	--	--	--
	*N	7	7	7	7	7	7	7	7	7	7	--	--	--
All Samples	x̄	1.72	3.13	.373	.241	.906	9.40	1.37	.455	1.23	11.98	47.55	6.91	14.1
	S.D.	3.56	.84	.155	.135	.727	9.84	1.36	.460	1.48	9.27	2.64	.39	1.01
	S.E.	.61	.14	.027	.023	.125	1.69	.23	.133	.25	1.59	.56	.08	.21
	*N	34	34	34	34	34	34	34	12	34	34	22	22	22

*Number of Samples.

CONTINUED

TABLE 22. CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

Fish-Muscle

(Activation Analysis Based on Wet Weight)

		mg/g Na	mg/g K	μg/g Rb	μg/g Zn	μg/g Hg	μg/g Se	μg/g Br	μg/g Fe
Dry I	$\bar{x}$	.588	3.39	3.99	6.74	.932	.411	2.76	4.70
	S.D.	.136	1.27	2.27	2.68	1.061	.264	2.00	3.31
	S.E.	.041	.38	.52	.61	.243	.061	.47	.88
	*N	11	11	19	19	19	19	18	14
Wet I	$\bar{x}$	.541	2.31	4.97	9.11	.290	.392	3.50	4.80
	S.D.	.145	1.48	2.16	3.84	.286	.223	.83	4.57
	S.E.	.072	.74	1.08	1.92	.143	.112	.48	2.29
	*N	4	4	4	4	4	4	3	4
Dry II	$\bar{x}$	.706	4.91	4.38	11.19	.277	.467	2.05	4.43
	S.D.	.221	1.09	2.43	5.52	.315	.439	1.51	3.46
	S.E.	.078	.39	.92	1.95	.112	.155	.53	1.22
	*N	8	8	7	8	8	8	8	8
All Samples	$\bar{x}$	.621	3.73	4.21	8.19	.680	.423	2.64	4.63
	S.D.	.176	1.53	2.24	4.09	.900	.304	1.80	3.40
	S.E.	.037	.32	.41	.73	.162	.055	.33	.67
	*N	23	23	30	31	31	31	29	26

*Number of Samples.

CONTINUED

TABLE 22. CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

Fish-Muscle

(Activation Analysis Based on Wet Weight)

		ng/g Ag	ng/g Cs	ng/g Sc	ng/g Cr	mg/g P	ng/g Sb	ng/g Co
Dry I	$\bar{x}$	.289	11.74	.139	15.97	1.77	.176	22.11
	S.D.	.191	9.32	.184	24.25	.26	.171	33.96
	S.E.	.045	2.14	.043	5.72	.07	.039	7.79
	*N	18	19	18	18	12	19	19
Wet I	$\bar{x}$	.638	18.11	.155	7.18	---	.206	29.05
	S.D.	.652	11.29	.184	3.44	---	.154	41.96
	S.E.	.326	6.14	.092	1.72	---	.077	20.98
	*N	4	4	4	4	---	4	4
Dry II	$\bar{x}$	---	12.84	---	35.47	---	---	25.30
	S.D.	---	8.96	---	27.99	---	---	26.64
	S.E.	---	3.17	---	9.90	---	---	9.42
	*N	---	8	---	8	---	---	8
All Samples	$\bar{x}$	.353	12.85	.142	20.00	---	.182	23.83
	S.D.	.360	9.51	.180	25.18	---	.165	32.24
	S.E.	.077	1.71	.038	4.60	---	.034	5.79
	*N	22	31	22	30	---	23	31

*Number of Samples

TABLE 23 . CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

FISH-BONE		Na	K	Cu	Mg	Ca	Zn	Sr	Cr	Mn	Fe	C	H	N
		(Chemical Analysis Based on Wet Weight)										(Dry Weight)		
		mg/g	mg/g	μg/g	mg/g	mg/g	μg/g	μg/g	μg/g	μg/g	μg/g	%	%	%
Dry I	$\bar{x}$	4.84	3.72	4.29	1.82	83.4	82.9	132.4	--	49.30	47.49	23.30	3.71	5.07
	S.D.	7.32	1.78	5.23	.92	75.3	27.5	67.9	--	31.32	58.88	6.52	.93	1.20
	S.E.	1.56	.38	1.14	.20	16.4	6.1	14.5	--	6.68	12.55	1.54	.22	.28
	*N	22	22	21	21	22	20	22	--	22	22	18	18	18
Wet I	$\bar{x}$	2.51	3.36	2.21	.90	65.4	36.7	32.2	1.14	12.21	89.91	27.75	4.50	7.02
	S.D.	1.09	1.94	2.69	.11	27.2	12.8	53.7	.68	7.45	169.51	1.53	.32	2.08
	S.E.	.49	.89	1.20	.05	12.2	5.7	24.0	.30	3.33	75.81	.76	.16	1.04
	*N	5	5	5	5	5	5	5	5	5	5	4	4	4
All Samples:	$\bar{x}$	4.40	3.65	3.89	1.64	80.06	73.66	113.8	--	42.43	55.34	24.11	3.85	5.43
	S.D.	6.66	1.78	4.88	.90	69.75	31.32	75.8	--	31.91	86.62	6.15	.90	1.54
	S.E.	1.28	.34	.96	.17	13.42	6.26	14.6	--	6.14	16.67	1.31	.19	.33
	*N	27	27	26	26	27	25	27	--	27	27	22	22	22

*Number of Samples

TABLE 24. CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

(Chemical Analysis Based on Wet Weight)

FISH-SKIN;HEAD;FINS		mg/g Na	mg/g K	µg/g Cu	mg/g Mg	µg/g Ca	µg/g Zn	µg/g Sr	µg/g Cr	µg/g Mn	µg/g Fe
Dry I											
	$\bar{x}$	2.43	1.94	.871	1.04	21.83	43.29	30.84	--	12.86	80.98
	S.D.	3.84	.32	.387	1.56	16.84	14.36	34.30	--	8.78	129.71
	S.E.	.88	.07	.084	.34	3.68	3.29	7.48	--	1.92	28.31
	*N	21	21	21	21	21	21	21	--	21	21
Wet I											
	$\bar{x}$	2.09	2.25	.920	.67	33.32	23.38	7.21	.396	6.20	89.73
	S.D.	.69	.41	.293	.27	14.60	12.95	6.80	.189	6.00	130.65
	S.E.	.31	.18	.131	.12	6.53	5.79	3.04	.084	2.68	58.43
	*N	5	5	5	5	5	5	5	5	5	5
All Samples:											
	$\bar{x}$	2.74	2.00	.881	.954	24.04	36.13	26.29	--	11.58	82.66
	S.D.	4.08	.35	.366	1.417	16.80	18.74	32.23	--	8.63	127.29
	S.E.	.80	.07	.072	.278	3.30	3.68	6.32	--	1.69	24.96
	*N	26	26	26	26	26	26	26	--	26	26

*Number of Samples

TABLE 25. CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA.

Miscellaneous Organisms

Sample Description	(Chemical Analysis Based on Wet Weight)										(Dry Weight)		
	mg/g Na	mg/g K	µg/g Cu	mg/g Mg	mg/g Ca	µg/g Zn	µg/g Sr	µg/g Cr	µg/g Mn	µg/g Fe	% C	% H	% N
FISH													
Smoked Mojarra-Fish Tissue													
Rio Nercua, Lower 3/16/67	954.00	5.82	1.20	1.26	46.8	4.4	4.9	1.0	20.2	127	--	--	--
CRUSTAEANS													
Shrimp Muscle													
Rio Chico 2/25/67	1.07	1.74	35.4	1.07	4.65	38.0	10.9	--	21.9	387	46.6	6.6	14.4
Entire Shrimp													
Rio Sabanas 2/20/67	1.27	2.72	21.2	.38	1.02	23.2	20.0	--	7.7	31	44.8	6.8	13.2
Rio Cuadi 3/19/67	.80	1.43	38.0	.32	2.20	22.8	14.9	--	5.0	103	--	--	--
Crayfish Muscle													
Rio Pierre 2/27/67	1.25	2.39	44.0	.84	3.13	23.4	8.8	--	18.5	271	47.5	8.8	12.9
REPTILES													
Turtle Muscle													
Rio Pierre 2/24/67	1.49	1.41	0.67	.16	.21	49.8	6.7	--	<.8	50	51.2	7.2	14.9
Cayman Tail Muscle													
Q. Uraseca 3/25/67	1.09	2.77	0.68	.22	.23	10.4	--	--	.7	10	48.9	6.9	14.2
GASTROPOD													
Snail Muscle													
Rio Morti, Hydro 3/16/67	.71	1.19	19.9	.98	5.15	9.45	6.9	--	17.5	45	46.3	6.7	13.2

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TABLE 25. CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

) Miscellaneous Organisms

(Activation Analysis Based on Wet Weight)

Sample Description	% Error	mg/g Na	mg/g K	μg/g Rb	μg/g Zn	μg/g Hg	μg/g Se	μg/g Br	μg/g Fe
		±10	±10	±10	±5	±30	±13	±5	±10
FISH									
Roe from Sabaleta fish									
Rio Nercua, Lower 8/28/67*		.6	1.9	368.0	149.0	<.05	.92	3.9	70.5
CRUSTACEANS									
Shrimp Muscle									
Rio Chico 2/26/67		--	--	1.6	37.9	~2.7	.85	1.8	14.6
Crayfish Muscle									
Rio Pirre 2/27/67		--	--	2.7	13.7	~2.7	.57	3.7	2.0
REPTILES									
Turtle Muscle									
Rio Pirre 2/24/67		--	--	2.0	50.5	~2.2	.35	1.1	20.2
Cayman Tail Muscle									
Q. Uruseca 3/25/67		--	--	2.9	6.3	~2.2	.21	1.8	2.6
GASTROPOD									
Snail Muscle									
Rio Morti, Hydro 3/16/67		--	--	1.2	11.6	~2.1	.17	3.1	19.5

*Based on dry weight.

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TABLE 25. CONCENTRATION OF ELEMENTS IN SAMPLES FROM PANAMA AND COLOMBIA

) Miscellaneous Organisms

(Activation Analysis Based on Wet Weight)

Sample Description	% Error	ng/g Ag ±50	ng/g Cs ±15	ng/g Sc ±5	ng/g Cr ±10	ng/g Sb ±10	ng/g Co ±5	mg/g P ±10
FISH								
Roe from Sabaleta fish Rio Nercua, Lower 8/28/67*		16.3	<20	1.8	35	3.8	58	--
CRUSTACEANS								
Shrimp Muscle Rio Chico 2/25/67		12	4	56	97	2.2	100	.023
Crayfish Muscle Rio Pirre 2/27/67		13	4.0	1.2	11	.8	14	.020
REPTILES								
Turtle Muscle Rio Pirre 2/24/67		.2	2.4	1.2	36	.7	4	.012
Cayman Tail Muscle Q. Uruseca 3/25/67		.2	6.5	.3	65	1.1	.8	.017
GASTROPOD								
Snail Muscle Rio Morti, Hydro 3/16/67		.6	1.4	.8	287	.2	10	.015

*Based on dry weight.

TABLE 26. CONCENTRATION OF STABLE ELEMENTS (LITERATURE VALUES)

(Analysis Based on Wet Weight)

Fish	mg/g Na	mg/g K	mg/g Cu	mg/g Mg	mg/g Ca	mg/g P	mg/g Pb	mg/g Fe	mg/g Cl	mg/g I	mg/g As
(1) Salmon-muscle	1.200	3.400		.320	.170	.230			1.900		
(1) Eel-muscle	.500-.950	1.900-2.450		.144	.090-.160	2.000			.500-1.100		
(2) Freshwater fish muscle	.560	1.330-4.400	.0025	.300	.300	2.200		.010		.300	
(2) Whole fish							.00005-.0002				
(2) Eviscerated fish											.0003
(3) Whole brook trout (<30 g body wt.)				.140-.200	3.600-4.200	3.100-4.600					
(4) Tench-muscle								.006			
" whole								.0258			

(1) Spector, W. S. 1956.

(2) Causeret, J. 1962.

(3) Phillips, A. M., Jr.; Lovelace, F. E., Brockway, D. R. and Balzer, G. C., Jr. 1952.

(4) Hevesy, G., Lockner, D. and Sletten, K., 1964.

TABLE 27. CONCENTRATION OF ELEMENTS IN CICHLIDS MAINTAINED IN COLUMBIA RIVER WATER, U.S.A.

II) FISH *Aequidens portalegrensis*

		(Chemical Analysis Based on Wet Weight)											(Dry Weight)		
		mg/g Na	mg/g K	μg/g Cu	mg/g Mg	mg/g Ca	μg/g Zn	μg/g Sr	μg/g Cr	μg/g P	μg/g Mn	μg/g Fe	% C	% H	% N
Muscle	$\bar{x}$	.64	2.60	.235	.25	.62	3.30	.42	.201	NA	.149	3.64	48.1	6.8	13.9
	S.E.	±.04	±.15	±.021	±.02	±.14	±.32	±.03	±.026		±.020	±.53	±1.1	±.2	±.4
Bone	$\bar{x}$	1.31	1.14	.280	.58	29.05*	8.65	11.41	.537*	NA	2.16	5.11*	33.2	4.9	8.1
	S.E.	±.38	±.39	±.125	±.16	±8.2	±2.61	±3.95	±.127		±1.24	±1.07	±2.7	±.4	±.5
Skin-Head Fin	$\bar{x}$	2.25*	1.24*	.478	.505*	33.95*	16.20*	7.95*	.421*	NA	11.91*	6.32*	NA	NA	NA
	S.E.	±.14	±.03	±.062	±.066	±2.93	±2.12	±.51	±.023		±.30	±.35			

Five samples per mean except four where noted by *.

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TABLE 27. STABLE ELEMENT CONCENTRATION FACTOR IN CICHLID MAINTAINED IN COLUMBIA RIVER WATER

FISH - Aequidens portalegrensis

(Chemical Analysis; Tissue Based on Wet Weight)

	Na	K	Cu	Mg	Ca	Zn	Sr	Cr	Mn	Fe
Muscle	333	3610	<78	58	28	27	5	<20	<15	140
Bone	682	1580	<70	134	1320	71	140	<54	<22	196
Skin-Head and Fin	1170	1720	<159	116	1546	133	97	<42	<1190	243

NATURAL AND WEAPON TEST FALLOUT - RADIONUCLIDES IN THE FRESHWATER ECOSYSTEM

Although weapon test fallout radionuclides concentrations in air and rainwater are low in the latitudes of Panama and Colombia, it was decided to apply ultra low level measuring techniques. Selected samples were also analyzed radiochemically for ^{90}Sr. Whilst these could only be spot samples, it was considered that they might indicate some unique features of biological concentration in a tropical freshwater ecosystem.

The data is presented in Tables 8 - 31.

The approximate concentration factors for whole fish for the nuclides ^{90}Sr, ^{137}Cs, and ^{60}Co are ~100, ~3000 and ~50 respectively. With the exception of the high value for ^{137}Cs these values compare reasonably well with the stable element concentration factors given in Table .

TABLE 28. RADIONUCLIDES WATER - DRY I

$pCi/10^3 l$

Station	River	Date	^{22}Na	^{40}K	^{60}Co	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	^{208}Tl	^{214}Bi
13	Pirre	2-24-67	---	14.4	2.13	---	---	---	---	2.79	0.85
11	Chico	3-6-67	---	1711.7	0.32	---	---	4.95	---	2.03	0.54
10	Tupiza	2-26-67	---	401.0	93.20	---	---	19.80	---	2.39	17.60
15	Yape	2-27-67	---	1547.0	13.90	---	---	2.25	---	---	0.72

RADIONUCLIDES SEDIMENTS - DRY I

pCi/kg*

Station	River	Date	^{22}Na	^{40}K	^{60}Co	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	^{208}Tl	^{214}Bi
8	Morti	3-16-67	0.76	8694.	1.80	---	---	450.	---	253.	136.
63	Atrato	3-21-67	---	9549.	---	---	---	---	---	486.	376.

*Dry Weight.

TABLE 29. RADIONUCLIDES TISSUE - DRY I

pCi/kg*

Station	River	Sample Type	Date	^{22}Na	^{40}K	^{60}Co	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	^{208}Tl	^{214}Bi
13	Pirre	Rhamdia wagneri	2/24/67	0.07	2432.	0.12	1.06	---	126.6	56.3	---	---
13	Pirre	Cichlasoma sp.	2/24/67	0.06	2345.	0.07	---	---	16.4	---	0.99	3.74
13	Pirre	Hoplias malabaricus	2/24/67	0.14	2436.	---	---	0.13	50.4	37.4	---	---
13	Pirre	Pimelodidae	2/24/67	---	2077.	---	---	---	18.6	51.8	---	---
14	Uruseca	Bryconamericus emperador	3/25/67	---	2136.	0.23	---	---	8.15	93.2	1.22	---
19	Mogue	Cichlasoma sp.	3/6/67	0.06	2677	0.05	---	---	30.6	40.1	---	0.85
11	Chico	Cichlasoma sp.	2/25/67	---	2404.	0.11	---	---	8.78	196.4	---	2.25
11	Chico	Ctenolucius beani	2/25/67	---	2836.	0.06	---	---	19.2	73.4	---	---
6	Chucunaque	Pimelodidae	3/1/67	0.17	2750.	0.13	---	---	19.4	---	6.58	3.51
58	Salado	Prochilodus magdalene	3/15/67	0.08	2491.	0.06	---	---	23.1	31.5	---	17.2
56	Quebrada Barrial	Brycon sp.	3/17.67	---	2545.	---	---	0.17	241.	23.0	---	1.67
63	Atrato	Ageneiosus caucanus	3/20/67	0.34	2150.	---	---	---	122.	---	---	0.49

*Wet Weight.

TABLE 30. RADIONUCLIDES

RADIONUCLIDES NOT DETECTED IN ANY SAMPLE

Isotope	Minimum Detectable Activity/kg* (pCi) pCi/kg
^{7}Be	3.500
^{46}Sc	0.039
^{54}Mn	0.287
^{65}Zn	0.650
^{88}Y	0.039
^{95}Zr-Nb	0.340
^{103}Ru	0.527
^{110m}Ag	0.231
^{124}Sb	0.095
^{125}Sb	1.950
^{140}Ba-La	0.090
^{207}Bi	0.059

RADIONUCLIDES DETECTED IN VARIOUS SAMPLES

^{22}Na	0.040
^{40}K	3.210
^{60}Co	0.050
^{106}Ru	0.750
^{134}Cs	0.072
^{137}Cs	0.036
^{144}Ce	33.300
^{208}Tl	0.810
^{214}Bi	0.320

*Defined as that sample activity which has an associated counting error at the 95% confidence level equal to 0.95 times the sample activity, and based on 1000 min. counting periods for both sample and background.

TABLE 31. ^{90}SR IN SELECTED RIVERS

Station	River	Date	pCi/l
2	Chucunaque	3-24-67	0.099
6	Chucunaque	3-17-67	0.194
8	Morti	3-16-67	0.163
11	Chico	2-24-67	0.025
12	Tuira	3-25-67	0.039
20	Sambu	3-25-67	0.045
21	Sabana	3-24-67	0.035
22	Congo	3-24-67	0.134
25	Cuadi	3-19-67	0.133
29	Grande	4-02-67	0.096
63	Atrato	3-19-67	0.110

^{90}SR IN WHOLE FISH

Station	Species	Date	pCi/kg
9	*Brycon* sp.	3-22-67	23.7
58	*Prochilodus magdalene*	[illegible]-15-67	19.0

SECTION X

CONCENTRATION FACTORS

Concentration factors, (concentration of element wet weight/concentration of the element in water) were calculated from the mean values for each of the elements determined in the biological samples from Routes 17 and 25 and are given in Table 32 by season and for all samples. Differences between season reflect the variability in concentrations of element in the biological samples rather than the differences between seasons for the river water samples.

The greater than values for Cu, Zn, Cr, Cs and Se reflect concentrations of elements at or below the limit of detection. Comparison with published literature values (Table 33) shows that the values for Cu, Zn and Cr in muscle tissue are low by about a factor of two or three. Caesium values, on the basis of the relationship developed by Preston et al, 1967 are low by at least on order of magnitude. This is confirmed by the radionuclide data (Section IX). The calcium and strontium accumulation factors for fish muscle and bone are comparable with the data of Templeton and Brown (1964). The accumulation factor for copper in crustaceans muscle is two to three times higher than that reported by Viswanathan et al (1966). Potassium concentration factors for fish muscle are slightly higher than those predicted by Viswanathan et al (1966). Because of the low levels of phosphorus in the water, concentration factors will be extremely high. From the data of Viswanathan et. al. (1966) a value of 64,000 would be expected with little difference between fish and crustaceans. A similar relationship was established for potassium and iron.

High concentration factors for mercury are predicted since the concentration in the water was below the limit of detection (0.04 μg/l). A concentration factor of 1.1 X 10^5 is reported by Hasselrof (1968) for pike. Tungsten was not detected in the biological samples, and was below the limit of detection for water (1.0 mg/l).

Overall, the concentration factors derived from this survey are compatible with the published literature. Both phosphorus and caesium are at the higher end of their ranges, due to the low concentrations of these elements present in the waters.

These low concentrations in the water may reflect a high capacity for retention and cycling of these elements in the terrestrial ecosystem.

Elements have been ranked in order, based on concentration factors for fish and crustacean muscle in Table 34 .

A review of the published concentration factors for stable and radioactive elements are presented in Table 33 .

Those elements which were not determined but could be significant are discussed below.

The concentration factors for the rare earths in the freshwater environment reported in the literature are high. It is likely that they will exist as hydroxides with low solubility, and accumulation will be partly related to the surface area of the organism. Hence, fish, with a low ratio of body surface to volume have relatively low values.

Filter feeding organisms on the other hand show factors in the upper range. Values of 10^3 - 10^4 are not uncommon for ^{144}Ce. In constrast, fish are reported to range from 0.13 to 3.2 in the Clinch River. Because of their physico-chemical form, these elements are likely to contribute significantly to the external radiation dose.

^{95}Zirconium in environmental contamination has been found in a wide variety of organisms and usually appears to be associated with adsorption, surface contamination and the ingestion of particulate matter. It is likely to be a contributor to external radiation hazards. Concentration factors in freshwater plants range from 10^2 to 10^4 though considerably lower in freshwater animals, being in the range $10 - 10^2$ (Polikarpov 1966).

Plutonium is considered to be a significant radionuclide in these studies. However, no information is available on concentration factors in the freshwater environment. However, it is similar chemically, goechemically and biogeochemically to the elements, thorium, cerium and zirconium.

These elements are easily hydrolyzed in aqueous solution and tend to form colloids. The ability of plutonium to adsorb onto surfaces results in its being tightly bound to biological and geological substrates (Wilson and Cline 1966, Templeton, W. L. 1966, Amphlett, C. B. 1961). Its uptake into food webs is likely then to be restricted, and in rivers will be mainly associated with suspended solids. Filter feeding organisms and those with large surface to volume areas would likely be more critical than fish. Similar values to cerium and zirconium should apply.

The data on the concentration factors for Ruthenium are extremely sparse for the freshwater environment and are limited mainly to plants and invertebrates with values of 10^3 not uncommon. The uncertainities of the chemical form of ruthenium complexes have complicated many of the environmental studies. It is, however, readily adsorbed to sediments and biological material in the natural environment. A concentration factor of 10 - 10^2 should apply to fish.

Tritium is present in fresh water at concentrations ranging from 1.7-5.2 X 10^{-18} (tritium per atom protium). However, there seems to be considerable latitudinal effect and the concentration in the fresh water will depend upon the rainfall history of the drainage area.

The incorporation of tritium oxide into tissue sites with a low metabolic turnover is very slow and is accomplished only after exposure for very long periods of time at high levels. Also, organisms preferentially use substrate H to meet such requirements rather than the H in body water (Thompson and Ballou, 1956).

In the muscle of fish from Panama and Colombia, the free water fraction of the tissue was about 78%. The free water of the tissue contained 8.74 grams H per 100 grams of wet tissue. The tissue hydrogen fraction based on 100 grams of wet tissue was 1.46 grams while 14.4% of the total H was in the tissue bound fraction.

The physiology of the freshwater organisms is such that there is an exceedingly high rate of water transport through the system. Thus, it is probable the tritium concentration in the free water of the tissue will equilibrate with the environment very quickly. The rate of exchange will be on the order of hours and days rather than months or years. It is unlikely that the concentration factor will exceed 1 as the organism actively discriminates against the incorporation of H from the free water into the tissue H fraction.

TABLE 32 . STABLE ELEMENT CONCENTRATION FACTORS IN SAMPLES FROM PANAMA AND COLOMBIA

(Chemical and Spectrographic Analysis Based On Wet Weight)

FISH	Na	K	Cu	Mg	Ca	Zn	Sr	Cr	Mn	Fe
Fish-Muscle										
Dry Season #1	293	3360	>65.8	42.7	50.7	>906	29.8	--	82.4	94.4
Wet Season #1	111	3570	>64.7	49.1	66.3	>338	9.09	>13.9	22.4	104
Dry Season #2	135	4570	>48.8	59.3	83.9	>429	20.2	>33.3	78.2	194
All Fish-Muscle Samples	234	3640	>62.2	47.0	59.8	>671	24.9	>25.3	72.4	116
Fish-Bone										
Dry Season #1	658	4330	>715	355	5510	>5920	2410	--	2900	461
Wet Season #1	341	3910	>368	175	4320	>2620	585	>63.3	718	873
All Fish-Bone Samples	598	4240	>648	320	5290	>5260	2070	>63.3	2500	537
Fish-Skin;Head;Fins.										
Dry Season #1	330	2260	>145	203	1440	>3090	56.1	--	756	786
Wet Season #1	284	2620	>153	131	2200	>1670	131	>22.0	365	871
All Fish-Skin;Head;Fins	372	2330	>147	186	1590	>2580	478	>22.0	681	803
CRUSTAEANS										
Shrimp-Muscle	145	2020	>5900	209	307	>2710	198	--	1290	3760
Shrimp-Entire										
Rio Sabanas	173	3160	>3530	74.1	67.4	>1660	364	--	453	301
Rio Cuadi	109	1660	>6330	62.4	145	>1630	271	--	294	1000
Crayfish-Muscle	170	2780	>7330	164	207	>1670	160	--	1090	2630
REPTILE										
Turtle-Muscle	202	1640	>112	31.2	13.9	>3560	122	--	<47.1	485
Cayman-Muscle	148	3220	>113	42.9	15.2	> 743	--	--	41.2	97.1
GASTROPOD										
Snail-Muscle	96.5	1380	>3320	191	340	>675	125	--	1030	437

CONTINUED

TABLE 32 . STABLE ELEMENT CONCENTRATION FACTORS IN SAMPLES FROM PANAMA AND COLOMBIA

(Activation Analysis Based On Wet Weight)

FISH	Na	*K	**Rb	Ag	Cs	Zn	**Hg	Sc
Fish-Muscle								
Dry season #1	75.9	3940	2660	0.734	>240	267	11600	1.62
Wet season #1	69.8	2690	3310	1.62	>370	361	3630	1.80
Dry season #2	91.1	5710	2920	—	>262	443	3460	—
ALL Fish-Muscle Samples:	80.1	4340	2810	0.896	>262	324	8500	1.65
CRUSTAEANS								
Shrimp-Muscle	--	--	1090	31.0	> 89.2	1500	33400	656
Crayfish-Muscle	--	--	1810	34.0	> 74.3	543	33400	14.4
REPTILES								
Turtle-Muscle	--	--	1330	<0.508	> 50.0	1980	27500	13.5
Cayman Muscle	--	--	1890	<0.508	>131	249	27500	3.26
GASTROPOD								
Snail-Muscle	--	--	813	1.60	> 28.2	463	27100	9.40

*Elemental concentration in water determined by chemical analyses

**Elemental concentration in water after Livingstone (1963)

CONTINUED

TABLE 32 . STABLE ELEMENT CONCENTRATION FACTORS IN SAMPLES FROM PANAMA AND COLOMBIA

(Activation Analysis Based On Wet Weight)

FISH	*Cr	*P	Sb	**Se	**Br	*Fe	Co
Fish-Muscle							
Dry season #1	>0.882	--	0.946	>20.6	131	45.6	75.7
Wet season #1	>0.399	--	1.11	>19.6	167	46.6	99.5
Dry season #2	>1.97	--	--	>23.4	97.6	43.0	86.6
ALL Fish-Muscle Samples:	>1.11	--	0.978	>21.2	126	45.0	81.6
CRUSTAEANS							
Shrimp-Muscle	>5.40	(207×10^5)	12.0	>42.6	88.1	1420	341
Crayfish-Muscle	>0.622	(179×10^5)	4.44	>28.6	178	23.6	47.6
REPTILES							
Turtle-Muscle	>2.00	(111×10^5)	3.98	>17.4	49.5	194	12.3
Cayman-Muscle	>3.56	(151×10^5)	5.70	>10.6	86.7	25.2	2.74
GASTROPOS							
Snail-Muscle	>16.0	(135×10^5)	1.27	>8.55	148	191	34.2

*Elemental concentration in water determined by chemical analyses

**Elemental concentration in water after Livingstone (1963

TABLE 33. CONCENTRATION FACTORS - LITERATURE VALUES

Organism	Na C.F	Na Ref.	K C.F	K Ref.	Cu C.F	Cu Ref.	Rb C.F	Rb Ref.	Cs C.F	Cs Ref.	Mg C.F	Mg Ref.	Ca C.F	Ca Ref.
Phytoplankton	168	C.R.*	1960	C.R.*	7600	C.R.*					419	C.R.*	17.9	C.R.*
	500	1**			2000	1**	99	24***					17	24***
Green Algae	500	1**			500	1**	538	24***	400 to 4000	7**			79	24***
							550	24***	1200	18**			414	24***
									1920	26***			99	47***S
									140	33***			145	47***S
									150	34***			1250	47***S
									500	34***			10700	47***S
									60	34***			980	56**S
Freshwater Plants	12.4	51***							300 to 1500	26***			327	56**
	114	51***												
	13	51***												
	44.5	51***												

* Columbia River

** Environmental

*** Laboratory

S Stable

CONTINUED

TABLE 33. CONCENTRATION FACTORS - LITERATURE VALUES

Organism	Zn		Sr		Y		Hg		Cr		P		Mn	
	C.F	Ref.	C.F	Ref.	C.F	Ref.	C.F	Ref.	C.F	Ref.	C.F	Ref.	C.F	Ref.
Phytoplankton	25100	C.R.*							1750	C.R.*	6150	C.R.*	42700	C.R.*
	183	24***	75000	1**							200000	1**		
											150000	1**		
											11000	28***		
Green Algae	922	24***	500000	1**	40000	26***			5300	26***	100000	1**		
	7447	24***	600	18**	119625	26***					135000	26***		
	6000	18***	1910	26***							76750	26***		
	31500	26***	900	34***							8600 to 18000	28***		
			1400	34***							300000	31***		
			97 to 18600	47***							9000	34***		
			75.4	52***							4000	34***		
			808	56							1100	34***		

*Columbia River

**Environmental

***Laboratory

CONTINUED

TABLE 33. CONCENTRATION FACTORS - LITERATURE VALUES

Organism	Zn C.F	Zn Ref.	Sr C.F	Sr Ref.	Y C.F	Y Ref.	Hg C.F	Hg Ref.	Cr C.F	Cr Ref.	P C.F	P Ref.	Mn C.F	Mn Ref.
Freshwater Plants			515	11***										
			131	11***										
			113	11***										
			408	11***										
			41	11***										
			86	11***										
			25 to 1910	12***										
			605	44***										
			527	44***										
			54.1	52***										
			200 to 1000	26***										
			270	56										

*** Laboratory

CONTINUED

TABLE 33. CONCENTRATION FACTORS - LITERATURE VALUES

Organism	S		Fe		Ru		Co		Zr		Ce	
	C.F	Ref.	C.F	Ref.	C.F	Ref.	C.F	Ref.	C.F	Ref.	C.F	Ref.
Phytoplankton	---------		---------		---------		-----------		---------		----------	
	118	24***	200000	1**			92	24***	1336	24***		
			1800	24***								
Green Algae	39	24***	100000	1**	500	34***	469	24***	4614	24***	37000	26***
	795	24***	7450	24***	3300	34***	1333	24***	16840	24***	35600	26***
	2600	26***	738	24***					32300	26***	250	34***
			31500	26***					71250	26***	1200	34***
									400	34***	74	27**
									1100	34***		
Freshwater Plants					250 to 2500	35**			360 to 8000	35**	200 to 1000	35**
					600 to 3000	26***					4000 to 20000	26***

** Environmental

*** Laboratory

CONTINUED

TABLE 33. CONCENTRATION FACTORS - LITERATURE VALUES

Organisms	Na C.F	Na Ref.	K C.F	K Ref.	Cu C.F	Cu Ref.	Rb C.F	Rb Ref.	Cs C.F	Cs Ref.	Mg C.F	Mg Ref.	Ca C.F	Ca Ref.
Aquatic insects	469	C.R.*			3970	C.R.*							14.6	C.R.*
	100	1**			500	1**			800	7***				
									4500	53**				
Microcrustacea									1100	7**				
									400	34***				
Crayfish, Prawns muscle									3900	29**			42 to 200	39**
													9 to 218	40**
whole									1360	26***				
									50 to 200	36***				
Tubificid worm													1.8 to 16.5	45***S
Snail-soft parts	13.6 to 112	51***							1200	29***				
									600	7***				
shell														
whole														

*Columbia River **Environmental ***Laboratory S Stable

CONTINUED

TABLE 33. CONCENTRATION FACTORS - LITERATURE VALUES

Organism	Zn C.F	Zn Ref.	Sr C.F	Sr Ref.	Y C.F	Y Ref.	Hg C.F	Hg Ref.	Cr C.F	Cr Ref.	P C.F	P Ref.	Mn C.F	Mn Ref.
Aquatic insects	7400	C.R.*							492	C.R.*	9230	C.R.*	10400	C.R.*
			100000	1**							100000	1**		
			744	53**							86000	28***		
											41000	28***		
											80000	28***		
											45000	28***		
											10000	28***		
Microcrustacea			31-57	11***							3800	28***		
			2400	34***							1700	34***		
Crayfish, Prawns muscle	12 to 4000	35**S	110	29**							19 to 309	39**	25,000	35**S
	3000 to 12800	54***									19 to 309	40**		
	40000	29**												
whole	8340	35**S												
	4400	54***												
Tubificid worm			3.1 to 16.5	45***										
Snail-soft parts	11800	29**	233	29**							9000	31***		
shell			31000	26***	2020	26***					35600	26***		
whole											850	31***		

* Columbia River
** Environmental
*** Laboratory
S Stable

CONTINUED

TABLE 33. CONCENTRATION FACTORS - LITERATURE VALUES

Organism	S		Fe		Ru		Co		Zr		Ce		T	
	C.F	Ref.	C.F	Ref.	C.F	Ref.	C.F	Ref.	C.F	Ref.	C.F	Ref.	C.F	Ref.
Aquatic insects			24600	C.R.*			9550	26***						
			100000	1**										
Microcrustacea											400	34***		
Crayfish, prawns muscle			19 to 128	39**S			625	29**						
			19 to 309	40**S										
whole							135 to 334	15***						
Snail-soft parts							71	29**						

*Columbia River

**Environmental

***Laboratory

S Stable

CONTINUED

TABLE 33. CONCENTRATION FACTORS - LITERATURE VALUES

Organism	Na C.F	Na Ref.	Cu C.F	Cu Ref.	Rb C.F	Rb Ref.	Cs C.F	Cs Ref.	Ca C.F	Ca Ref.	Zn C.F	Zn Ref.	Sr C.F	Sr Ref.
Clam-soft parts			200	57**S			149	25***	5.4	57**S	3000	29***	136	25***
							200	34***					730	30**S
							2.2 to 3.5	48***					400	34***
							280	29***					35	29***
													257	57**S
Fish-flesh	15 to 109	41**S	109	41**S	844	41**S	3000	7***	7	39**	1600	18**	0.009 to 0.091	10**
			2 to 110	42**S			9500	7***	56	40**	600	18**	0.007 to 1.25	10**
			10	57**S			900	18**	55	41**S	800	18**	0.02 to 1.98	10**
							1200	18**	23 to 401	42**S	1700	29**S	1.0	13**
							1200	18**	6.7	56**S	1330	35**	<48	18**
							533	29**S	5	57**S	1330	35**	23.6	29**
							2500 to 3600	35**			863	41**S	5	30**S
							85	41**S			140	29**	1	32**
							3900	49**			150	57**S	21	35**
							83	29**					1.3 to 91.	36**S
													1.7 to 125	36**S
													3 to 198	36**S

** Environmental
*** Laboratory
S Stable

CONTINUED

TABLE 33. CONCENTRATION FACTORS - LITERATURE VALUES

Organism	Na C.F	Na Ref.	Cu C.F	Cu Ref.	Rb C.F	Rb Ref.	Cs C.F	Cs Ref.	Ca C.F	Ca Ref.	Zn C.F	Zn Ref.	Sr C.F	Sr Ref.
Fish-flesh (continued)													0.75 to 1.17	37***
													11	41**S
													3 to 100	46**S
													0.027 to 208	50**S
													0.33 to 89.1	50**S
													2.2	29**
													2.6	56**S
													1	57**S
Fish-bone			<140	57**S					8200	57**S	1100	57**S	3000	30**S
									600	56**S			3884	32**
													2420	35**
													50 to 9170	36**S

**Environmental
***Laboratory
S Stable

CONTINUED

TABLE 33. CONCENTRATION FACTORS - LITERATURE VALUES

Organism	Hg C.F	Hg Ref.	Cr C.F	Cr Ref.	P C.F	P Ref.	Mn C.F	Mn Ref.	Fe C.F	Fe Ref.
Clam-soft parts					788	25***	30000 to 40000	3**S	3300	57**S
					1500	34***	14100	57**S		
Fish-flesh	110000	58**S	54	41**S	26037	40**	143	41**S	51	39**S
			1.22	59***S	6240 to 19730	42**S	30	57**S	98	40**S
							100 to 400	35**S	7 to 999	42**S
									100	57**S
Fish-bone							2700	57**S	1100	57**S

**Environmental

***Laboratory

S Stable

CONTINUED

TABLE 33. CONCENTRATION FACTORS - LITERATURE VALUES

Organism	Ru C.F	Ru Ref.	Co C.F	Co Ref.	Zr C.F	Zr Ref.	Ce C.F	Ce Ref.	I C.F	I Ref.
Clam-soft parts	65	25***	354	29**	111	25***	127	25***		
					80	34***	125	34***		
Fish-flesh			44	29**					0.03	55**
			2.3	29**						
			67	41**S						
Fish-bone									3.23	55***

** Environmental

*** Laboratory

S Stable

CONTINUED

TABLE 33. CONCENTRATION FACTORS - LITERATURE VALUES

Organism	Na		Cu		Rb		Cs		Ca		Zn	
	C.F	Ref.	C.F	Ref.	C.F	Ref.	C.F	Ref.	C.F	Ref.	C.F	Ref.
Fish-bone	------		--------		--------		--------		--------		----------	
Fish-whole	100	1**	50	1**			10	34***			7600	35**
							516	38**S				
							349	38**S				
							640	38**S				
							163	38**S				
							138	38**S				
							0.8	48***				
							0.6	48***				
							0.5	48***				
							0.3	48***				

** Environmental
*** Laboratory
S Stable

CONTINUED

TABLE 33. CONCENTRATION FACTORS - LITERATURE VALUES

Organism	Sr C.F	Sr Ref.	Hg C.F	Hg Ref.	Cr C.F	Cr Ref.	P C.F	P Ref.	Mn C.F	Mn Ref.	Fe C.F	Fe Ref.
Fish-bone	71	56**S										
	2000	57**S										
Fish-whole	20000 to 30000	1**					100000	1**			10000	1**
	950	30**S					30000 to 70000	1**				
							165000	23***				
							32000	28***				
							120000	31***				
							100 to 200	34***				

** Environmental

*** Laboratory

S Stable

CONTINUED

TABLE 33. CONCENTRATION FACTORS - LITERATURE VALUES

Organism	Ru C.F	Ru Ref.	Co C.F	Co Ref.	Zr C.F	Zr Ref.	Ce C.F	Ce Ref.	I C.F	I Ref.
Fish-bone	----------		--------		----------		----------		-----------	
Fish-whole	10.4	27**	22	27**			3.2	27**		
	0.8	27**	0.5	27**			0.13	27**		
	0.3	27**								

** Environmental
*** Laboratory

TABLE 34. RANKED ORDER OF ELEMENTS BASED ON CONCENTRATION FACTORS

Fish Muscle	Crustacean Muscle
P	P
Hg	Hg
K	Cu
Cs	Fe
Rb	K
Zn	Zn
Na	Rb
Br	Cs
Fe	Mn
Co	Ce
Mn	Zr
Cu	Pu
Ca	Br
Mg	Co
Sr	Ca
Ru	Mg
Cr	Sr
Se	Sc
Ce	Ag
Zr	Sb
Pu	Cr
Sb	
Ag	

REFERENCE LIST

1. Krumholz, L. A. and Foster, R. F., 1957. "Accumulation and retention of radioactivity from fission products and other radiomaterials by fresh-water organisms." In "Effects of Atomic Radiation on Oceanography and Fisheries", Nat. Acad. Sci., Nat. Res. Council Publ. 551, p. 88-95.

2. Harrison, Florence L., 1967. "Accumulation and distribution of manganese-54 and zinc-65 in freshwater clams". UCRL-70307, 38 pp.

3. Merlini, M., 1967. "The freshwater clam as a biological indicator of radiomanganese" In "Radioecological Concentration Processes" B. Aberg and F. P. Hungate, eds., Proc. Int. Symp., Stockholm, April 1966, p. 977-982.

4. Chipman, W. A., 1966. "Uptake and accumulation of chromium-51 by the clam _Tapes decussatus_, in rleation to physical and chemical form." In "Disposal of Radioactive Wastes into Seas, Oceans and Surface Waters", Proc. Symp., Vienna, May 1966, IEAE, p. 571-582.

5. Nakatani, R. E., 1966. "Biological response of rainbow trout (_Salmo gairdneri_) ingesting zinc-65". IBID., p. 809-823.

6. Young, D. R. and Folsom, T. R., 1967. "Loss of Zn^{65} from the California sea-mussel _Mytilus californianus_", Biol. Bull., _133_: 438-447.

7. Pendleton, R. C. and Hanson, W. C. 1958. "Absorption of cesium-137 by components of an aquatic community" In Proc. 2nd U. N. Geneva Conf., p. 419-422.

8. Hasanen, E., Kolehmainen, S. and Miettinen, J. K., 1967. "Biological half-time of ^{137}Cs in three species of fresh-water fish: perch, roach and rainbow trout." In "Radioecological Concentration Processes", B. Aberg and F. P. Hungate, eds., Proc. Int. Symp. Stockholm, April 1966, p. 921-924.

9. Wlodek, S., 1967. "The behavior of ^{137}Cs in freshwater reservoirs, with particular reactions of plant communities to contamination", IBID., p. 897-912.

10. Agnedal, P. O., 1967. "Calcium and strontium in Swedish waters and fish, and accumulation of ^{90}Sr. IBID., p. 879-896.

11. Polikarpov, G. G., et al., 1968. "Strontium-90 in fresh and brackish bodies of water." In "USSR Reports on Radioactivity in Man and the Environment", HASL, N. Y., Jan. 1968, p. 161-186.

12. Timofeeva, N. A. and Kulikov, N. V., 1967. "The role of freshwater plants in accumulation of ^{90}Sr and its distribution over the components of reservoir." In "Radioecological Concentration Processes", B. Aberg and F. P. Hungate, eds., Proc. Inst. Symp., Stockholm, April 1966, p. 835-841.

13. Nelson, D. J., 1967. "The prediction of ^{90}Sr uptake in fish using data on specific activities and biological half-lives." IBID., p. 843-851.

14. Brungs, W. A., 1965. "Experimental uptake of strontium-85 by freshwater organisms.", Health Phys., 11:41-46.

15. Wiser, C. W. and Nelson, D. J. 1964. "Uptake and elimination of cobalt-60 by crayfish.", Amer. Midl. Nat. 72(1):181-202.

16. Watson, D. G., George, L. A. and Hackett, P. L. 1959. "Effects of chronic feeding of phosphorus-32 on rainbow trout". In "Hanford Biology Research Annual Report for 1958", A.E.C. Doc. HW-59500, p. 73-77.

17. Gaglione, P. and Ravera, O., 1964. "Manganese-54 concentration in fall-out, water, and Unio mussels of Lake Maggiore, 1960-1963". Nature, 204(4964):1215-1216.

18. Harvey, R. S. 1963. "Uptake of radionuclides by freshwater algae and fish." Health Phys.

19. Scott, D. P., 1961. "Radioactive iron as a fish mark." J. Fish. Res. Bd. Can., 18(3):383-391.

20. IBID. 1962. "Radioactive caesium as a fish and lamprey mark." J. Fish. Res. Bd. Can., 19(1):149-157.

21. Getsova, A. B., 1960. "The problem of the excretion of radioactive isotopes by various aquatic invertebrates" Transl. from Doklady Akad. Nauk SSSR. 133(2):459-461 July 1960.

22. Hunn, J. B. and Fromm, P. O., 1964. "Uptake, turnover and excretion of I-131 by rainbow trout (Salmo gairdneri)." Biol. Bull., 126 (2):282-290.

23. Davis, J. J. and Foster, R. F., 1958. "Bioaccumulation of radioisotopes through aquatic food chains." Ecology, 39(3):530-535.

24. Gileva, C. A., 1960. "Coefficients of radioisotope accumulation by fresh-water plants." Transl. from Doklady Akad. Nauk, SSSR 132(4):948-949 June 1960.

25. Garder, Karen and Skulberg, O., 1965. "Radionuclide accumulation by Anodonta piscinalis Nilsson (Lamellibranchiata) in a continuous flow system." Hydrogiologia 26(1-2):151-169.

26. Timofeeva-Resovskaya, E. A., Timofeev-Resovskii, N. V. and Gileva, E. A., 1961. "Specific accumulators of individual radioisotopes among freshwater organisms.", Transl. from Doklandy Akad. Nauk SSSR, 140(6):780-783.

27. Friend, A. G., Story, A. H., Henderson, C. R. and Busch, K. A., 1965. "Behavior of certain radionuclides released into fresh water environments. Annual Report 1959-1960", U. S. Public Health Serv. Publ. No. 999-RH-13, p. 37-59.

28. Whittaker, R. H., 1961. "Experiments with radiophosphorus tracer in aquarium microcosms." Ecol. Monog., 31:157-188.

29. Brungs, W. A., Jr., 1967. "Distribution of cobalt 60, zinc 65, strontium 85, and cesium 137 in a freshwater pond." U. S. Dept. Health, Education and Welfare, P. H. S. No. 999-RH-24, 52 pp.

30. Ophel, I. L., 1963. The fate of freshwater radiostrontium in a freshwater community. In Radioecology", V. Schultz and A. W. Klement, Jr. eds. Proc 1st Natl. Symposium and Radioecology, Col. St. Univ., For Collins, Col., Sept. 1961. Reinhold Publ. Fort Collins, Col., Dept 1961, Reinhold Publ Corp, N. Y. p. 213-216.

31. Whittaker, R. H., 1953. "Removal of radiophosphorus contaminenet from the water in an aquarium study" In "Biology Research-Annual Report 1952" HW-28636 p. 14-18.

32. Struxness, E. G. et al., 1967. "Clinch River Study" ORNL 4035, 121 p.

33. Harvey, R. S. and Patrick, R., 1967. "Concentration of ^{137}Cs, ^{65}Zn, and ^{85}Sr by fresh-water algae." Biotechnology and Bio-engineering. 9:449-456.

34. Garder, K. and Skulberg, O., 1966. "An experimental investigation on the accumulation of radioisotopes by fresh water biota." Arch. Hydrobiol., 62(1):50-69.

35. Bryan, G. W. and Ward, E., 1962. "Potassium metabolism and the accumulation of ^{137}Caesium by decapod crustacea." J. Mar. Biol. Assoc., 42:199-241.

36. Agnedal, P. O., 1966. "Calcium and strontium in Swedish waters and fish, and accumulation of strontium-90." Aktiebolaget Atomenergi, Stockholm, AE-224, 34 p.

37. Reed, J. R., Nelson, D. J. and Griffith, N. A., 1967. "Uptake and metabolism of strontium in bluegill flesh and blood." In "Radiation Ecology Section Progress in Terrestrial and Freshwater Ecology" ORNL-4168 Publ. No. 215, p. 93-97.

38. Nelson, D. J., Kevern, N. R. and Griffith, N. A. 1967. "Cesium and potassium in aquatic food chains." In "Radiation Ecology Section Progress in Terrestrial and Freshwater Ecology" ORNL-4168, Publ. No. 215, p. 97-98.

39. Viswanathan, R., Bhatt, Y. M., Naidu, J. R., Doshi, G. R. and Unni, K. 1962. "Mineral contents of freshwater organisms," Govt. India. Atomic Energy Establ. Trombay. AEET/HP/BS-1, 10 p.

40. Viswanathan, R., Bhatt, Y. M., Sreekuonaran, C., Doshi, G. R., Gogak, S. S., Bhagwat, A. M. and Unni, C. K., 1966. "Mineral content of aquatic foods." Proc. Indian Acad. Sci., 64:301-313.

41. Pillai, K. C., Ganapathy, S., Desai, M. V. M. and Ganguly, A. K., 1966, "Evaluation of acceptable limits for radioactive contaminants in the Chambal River - Rana Pratap Sagar." Indian Atomic Energy Establ. Trombay, AEET/HP/R-13, 75 p.

42. Bhatt, Y. M., Sreekumaran, C., Doshi, G. R., Gogate, S. S. Bhagwat, A. M., and Unni, C. K., 1963. "Mineral content of fresh waters and freshwater organisms. II Kaylan. Kolhapur and Juduguda Areas." Indian Atomic Energy Establ. Trombay. AEET/HP/BS-3, 11 p.

43. Patten, B. C. and Iverson, R. L., 1966. "Photosynthesis and uptake of strontium-85 in freshwater plankton." Nature, 211 (5044): 96-97.

44. Kulikov, N. V., Lyubimova, S. A. and Timofeeva, N. A., 1967. "The accumulation of certain radioisotopes by live and dead tissues of fresh-water plants." In "Radiobiologiya" A.E.C.-tr-6887, p. 181-187.

45. Whitten, B. K. and Goodknight, C. J. 1967. "The accumulation of St-89 and Ca-45 by an aquatic oligochaete," Physiol. Zool., 40 (4):371-385.

46. Templeton, W. L. and Brown, V. M., 1963. "Accumulation of calceium and strontium by brown trout from waters in the United Kingdom". Nature, 198(4876):198-200.

47. Pickering, D. C. and Lucas, J. W., 1962. "Uptake of radiostrontium by an alga, and the influence of calcium ion in the water." Nature, 193(4820):1046-1047.

48. Morgan, F. 1964. "The uptake of radioactivity by fish and shellfish. I. ^{134}Caesium by whole animals." J. Mar. Biol. Ass., 44(1):259-271.

49. Preston, A., Jeffries, D. F. and Dutton, J. W. R., 1967., "The concentrations of caesium-137 and strontium-90 in the flesh of brown trout taken from rivers and lakes in the British Isles between 1961 and 1966: the variables determining the concentrations and their use in radiological assessments." Water Research, 1: 475-496.

50. Templeton, W. L. and Brown, V. M., 1964. "The relationship between the concentrations of calcium, strontium, and strontium-90 in wild brown trout, Salmo trutta L. and the concentrations of the stable elements in some waters of the United Kingdom, and the implications in radiological health studies." Int. J. Air Wat. Poll., 8:49-75.

51. Fefedova, A. I. and Popova, E. I., 1965. "Distribution of sodium-22 among the components of a reservoir," Radiobiologiya, 5(3):170-177 AEC-tr-6600 (TID 4500).

52. Timofeeva, N. A. and Agre, A. L., 1965. "Coefficients of accumulation of strontium-90 by fresh-water plants from solutions of different specific activities", IBID, p 178-18.

53. Getsova, A. B. and Volkova, G. A., 1961. "Accumulation and excretion of strontium 90 and cesium 137 by larvae of the caddis fly Halesus interpunctatus Zett." Transl. from Doklady Akademii Nauk SSSR, 139(2):545-546.

54. Bryan, G. W., 1966. "The metabolism of Zn and ^{65}Zn in crabs, lobsters and fresh-water crayfish." In "Radioecological Concentration Processes." B. Aberg and F. P. Hungate, eds., Proc. Int. Symp. Stockholm, April 1966, p. 1005 to 1016.

55. Fromm, P. O., 1965, "Some aspects of radioiodine metabolism in marine teleosts." Bull. Inst. Oceanogr., Monaco, 64(1329): 12 p.

56. Templeton, W. L. 1959. "Fission products and aquatic organisms" In "Effects of Pollution on Living Material, W. B. Yapp, Ed., Symposia of the Institute of Biol., No. 8, P. 125-140.

57. Merlini, M., Berg. A., Gaglioni, P. and Ravera, O., 1967. "Lo studio degli elementi stabili e radioactivi in due ecosistemi acquatici (Novellino Lago Maggiore)." Giornale di Fisica Sanitari e Prortezione contro le Radiazioni: 12(4):156-158.

58. Hasselrot, T. B., 1968. "Report on current field investigations concerning the mercury content in fish, bottom sediments and water." Institute of Freshwater Res., Drottningholm, Rpt. No. 48, p. 102-111.

59. Fromm, P. O. and Stokes, R. M., 1962. "Assimilation and metabolism of chromium by trout." J. Wat. Pollut. Control. Fed. Nov. 1962, p. 1151-1155.

THE UTILIZATION OF THE FRESHWATER ECOSYSTEM

The freshwater ecosystem in the areas bounding Route 17 and Route 25 plays an important part in the life of the people since the majority of their activities are dependent on the river systems.

Probably the most important factor is transportation. The rivers have governed the movement and colonization of the area, though intervillage and interprovince trails are common. The economy is essentially based upon subsistence agriculture alongside the rivers. The freshwater system allows the Indians to extend their day-to-day agricultural operations up to tens of miles from the village which would be impossible if they had to rely on land trails. All commerce, whether for barter or commercial purposes, e.g. plantain and lumber are solely dependent upon riverine transportation.

All of the settlements, villages and towns, with the exception of La Palma, depend upon the rivers for their drinking, cooking and washing water. In La Palma the water supply is from shallow wells. The rivers also serve as a waste disposal system for both domestic garbage and sewage. In all areas, bodily cleanliness is of particular importance, especially amongst the Cuna and Choco Indians. Children spend many hours in the river, particularly during the dry season.

In the Cuna mountain villages basket making relies upon the river for the process. Vegetable material is soaked in the river to make the strips pliable for weaving. Unfinished work is ballasted and stored on the river bottom to maintain its pliability.

Last, but by no means unimportant to this program, is the source of protein in the form of fish, reptiles and macroinvertebrates such as crayfish, clams, snails,and reptiles. Fish are taken by spearing, by handlines, with dynamite, and occasionally in traps. Nowhere was seen evidence of net fishing though Bennett(1962) reports the prevalent use of nets in the Bayano. (Table 35).

In all areas with access to the sea it is interesting to note that marine food organisms are preferred to freshwater food organisms. For example, at Station 22 on the Rio Congo, the Choco Indians were preferentially using marine fish and crabs in their diet, despite the fact that freshwater fish and crustaceans were present in the river. At the same station there were large numbers of freshwater snails but they were not used as food. On the Rio Sambu, at Station 20, clams and snails were present in quantity in the river. The Choco did not use them but preferred to travel down river for oysters and marine crabs. On the other hand, on the Rio Morti,the Cuna at the village just below Station 8 used the large freshwater snail, Pomaca cumingii and crabs in their diet. The snails Nerita ornaga and Nerita latissima were also abundant in many rivers but neither apparently was ever used in the diet.

At Aligandi on the San Blas Islands, over 80% of the protein was derived from seafood sources. There was little evidence or indication that they ever used freshwater fish in the diet. They, however, did use the land crab, Cardiosoma sp. in their diet when available. The Cuna islanders are, however, completely dependent upon the rivers of the mainland for their drinking water which they transport to the islands. The women and children spend a considerable part of their day washing clothes and bathing in the rivers.

Although the people consume fish the year round, there seems to be more utilization in the so-called "dry" season when the rivers are low. In Colombia there seems to be a higher utilization of freshwater fish by the Negro population than there is in the Darien. In La Palma and El Real marine and estuarine fish from a large part of the small fish diet. There is some indication that the Negro consider freshwater fish "Indian food". A similar expression was made in Colombia with reference to the Bocachico (*Prochilodus magdalanae*)

The total intake of freshwater organisms, and the contribution to the diet by the different preferred species was difficult to judge. The Cichlidae, Loricaridae and *Sternopygus dariensis* were the preferred fish in the Darien. With the Upper Chucunaque Cuna, all species are taken with a preference for *Hypostomus plecostomus*. Of the macro-invertebrates, the crayfish is consumed, at times, in large quantities by the Choco, especially on the Lower Chucunaque and Chico.

Based on the data from the Human Ecology Group and that obtained by Bennett(1962) in the Bayano, it would seem that 100 g of freshwater organisms per day is a reasonable estimate.

Intake of water was more difficult to estimate but would seem to be of the order of 4.0 liters per day, though at least 3.0 liters would be consumed as a prepared beverage and in cooking.

In order to provide some data on the transfer of radionuclides from fresh whole fish to the diet, a series of fish samples from the Columbia River at Hanford were processed. The method used was typical of the cooking technique observed both in Panama and Colombia.

The fish were cleaned and boiled in water until the soft parts separated from the bones. The "soup" was then strained and the soft parts separated from the bones.

The data, expressed as per cent whole fish are given in Table 36.

Causeret (1962) reports on the changes in stable element concentrations in boiled fish. Fish muscle loses 28% of weight when boiled, and a loss of 40-60% of chloride, sodium and potassium and 20-30% of phosphorus, magnesium and calcium. When boiled with the bone, the calcium content of the muscle is 75% higher than muscle cooked without the bone. Phosphorus, however, is reduced by one third.

TABLE 35. LIST OF COMMON AND SCIENTIFIC NAMES OF MAJOR FOOD FISHES IN PANAMA AND COLOMBIA

Common Name	Scientific Name (species no.)
Sabaleta	Brycon sp. (8,9,10)
Cacuchos (C)	Loncaria sp. (68-70,72)
Bocachico (C)	Prochilodus magdalene (36)
(P)	Agonostomus monticola (102)
Barbudos (C)	Rhamdia wagneri (54)
(P)	Pimelodus clarias (52)
Sabalo (C)	Tarpon atlanticus
Robalos	Centiopomus sp.
Barbudos	
Bagre Sapo	Pseudopimelodus (53)
Doncella (P)	Pimelodella chagresi (51)
(C)	Ageneiosus caucanus (48)
Denton (C)	Hoplias malabaricus (27)
(C)	Leporinus myscorum (29)
Boguiancha (C)	Roeboides sp. (37)
Aguja	Tylosurus fluviatilignujeta (92)
Agujeta de escamas	Ctenolucios (18)
Biringo (C)	Sternopygus macrurus (45)
Jorokada (C)	Geophagus pellegrini (86)
Jurel (C)	Carans Lippos
Robalo congo	Ceatropomus ensiferns
	Tarpon atlanticus
Pargo (C)	Lutjamus jocu
Meros (C)	Carrupia sp.
Pez Espada (C)	Pristis pectinatus
Raya (C)	Potamotrygon magdalene (58,72)
Corona (C)	Hemiancistrus halostinetus

CONTINUED

TABLE 35. LIST OF COMMON AND SCIENTIFIC NAMES OF MAJOR FOOD FISHES IN PANAMA AND COLOMBIA

Common Name	Scientific Name (species no.)
Sabalo de Castillo	Brycon meeki (10)
Johorro (C)	Pomadasys bayamus (100)
Robalo (C)	Centropomus armatus
Congo (P)	Symbranchus marmoratus (88)
Pez perro (P)	Hoplias malabaricus (27)
Guacoco (P)	Plecostomus sp.
Machana (P)	Sternopygus dariensis (44)
Pez serra (P)	Pristis microdon
Sabalo real (P)	Tarpon atlanticus
Sardinas (P)	Astyanax (3-7)
Mojarra	Cichlidae (78-80)
Liza	Mngilidae (102-104)
Quirchara (c)	
Moncholo	Loricaria sp. (68-70,72)
Perrz braba	

(P) Species common to Panama

(C) speices common to Colombia

TABLE 36. TRANSFER OF RADIONUCLIDES FROM FISH TO DIET

(DATA EXPRESSED AS PER CENT WHOLE FISH)

	^{32}P	^{51}Cr	^{56}Mn	^{60}Co	^{65}Zn	^{46}Sc	^{137}Cs	^{140}Ba	^{140}La	^{59}Fe
Edible	14	18	27	47	45	22	16	21	14	21
Soup	53	57	18	3	7	38	60	45	66	28
Rest	33	25	55	50	48	40	24	34	20	51
% of radionuclide in whole fish transferred to diet	67	75	45	50	52	60	76	66	80	49

ESTIMATION OF POTENTIAL RADIATION DOSE

Whilst the most realistic method of estimating the potential radiation doses to human populations living in or near the probable fallout contamination may be with a dynamic model of radionuclide transfer through environmental and biological pathways leading to man. However, the lack of data on transfer coefficients that can be applied to this study limits its applicability.

However, less conservative but still acceptable approaches can be applied.

a) Specific Acitivity Concept.

The application of the specific activity concept is one method by which it is possible to predict the steady state distribution of a radionuclide released to an environment. The specific activity is the ratio of radioactive atoms to total atoms of the same element, the stable element in environmental samples being used as an analog for the radionuclide.

Some of the assumptions for applying this approach are:

1) stable and radioactive atoms of the element are completely mixed and behave similarly.
2) biological half-time is known.
3) organisms are in equilibrium with the environment.
4) concentrations of the stable element are known.
5) rates of growth are known.

6) rates of input of radioactive atoms are constant.

Kaye and Nelson (1968) have reviewed the concept as it applies to predictions of radionuclide movements through environmental pathways and conclude that the simple two-compartment model, e.g., water and critical organ, ignores several important parameters and requirements such as physical half-life, biological half-time, biological growth and time, that affect the accuracy of the prediction.

However, it is agreed that for this study it can provide guidance on those radionuclides which may be disregarded. Even in its fullest form, the concept does not provide an estimate of dose. A conservative prediction of the intake of a radionuclide can be made using the specific activity ratio in the detonation cavity or at a point later in time, and applying the ratio to the quantity of stable element in the freshwater component of the diet. Even if the input of radionuclides to the ecosystem was constant, the specific activity ratio in the food organisms would increase with time until the whole population was composed of individuals that had been exposed since hatching. Ophel (1963) in studies with a natural population of yellow perch (*Perca* sp.) at Chalk River showed that in excess of five years was required for equilibration to occur under chronic ^{90}Sr contamination conditions.

Exposure of adult fish indicates that at 42 days 30% and 10% equilibration had occurred in muscle and bone respectively of Rudd (Foreman and Bidwell, 1957). Reed, Nelson and Griffith (1967) report that in laboratory experiments with ^{89}Sr and fish that the flesh only reached one-tenth of the specific activity of the water in 35 days.

There is evidence that for those radionuclides which are known to exist in a "particulate" or complexed form, agreement with predicted values from stable element ratios can be poor, due presumably to the existance of the radionuclides in a more readily available chemico-physical form.

b) Concentration Factor Concept.

The concentration factor concept, using either stable element or radionuclide data requires acceptance of many of the same basic assumptions outlined in (a) for the application of the specific activity concept. The concentration or accumulation factor is defined as the ratio of the concentration of the stable element or radionuclide in a tissue or organism to the concentration of the same element or radionuclide in an equal weight of medium. The stable element data provides a concentration factor that represents true time equilibrium, and reflects the total contribution from water and the diet of the organism. The majority of data for radionuclides has been obtained from short-term studies with the exception of those environmental studies with radionuclides having long physical half-lives and where equilibration has occurred (Templeton and Brown 1964, Preston et al, 1967, Nelson 1967, Agnedal 1967 and Kolehmainen, 1967). (Table).

The rapid equilibration of the order of 20 to 40 days for fish and macroinvertebrates is misleading since it represents only an equilibrium between the water and the fast components of the accumulation rate. This is subsequently followed by a slow rate of accumulation that is probably related to growth. Adult organisms probably never reach 100 per cent equilibration. Fish hatched in a constant concentration of ^{90}Sr and raised to fingerling size have a concentration factor that is identical to that predicted from stable strontium and a specific activity ratio the same as the water. Detailed studies on this aspect have been limited to ^{89}Sr and ^{90}Sr.

In the case of those elements which are not readily transferred through the food webs to man, but whose chemistry indicates are readily adsorbed on surfaces, equilibration does not depend upon metabolic processes. The rates of accumulation are likely to be relatively fast reflecting the concentration in the water. Experimental values for the biological half-life have not been determined but in the case of those radionuclides adsorbed to the mucous surfaces of fish it is considered to be of the order of days.

Perhaps the most crucial assumption for both concepts refers to the constant input to the ecosystem. The proposed detonation schedule indicates that rows of devices will be fired over a period of years and consequently peak concentrations of fallout will occur.

However, as far as the freshwater ecosystem is concerned, the contribution from direct fallout is likely to be small since a high percentage of the river cross-sections are covered by the vegetation canopy. Whether peak concentrations of radionuclides will be experienced by the ecosystem depends more upon the flow through the terrestrial and ground water systems predicted by other groups. If it is shown that these systems, because of their retention capacity and slow turnover times, dampen out the peaking effect, the application of these concepts will be less conservative.

TABLE 37. RADIONUCLIDE HALF-TIMES, SPECIFIC ACTIVITIES*, AND EQUILIBRATION TIMES IN BIOLOGICAL MATERIALS - LITERATURE VALUES

Sample Type	Effective $T_{1/2}$	Biological $T_{1/2}$	Specific Activity	Time to equilibrium	Ref.**
			^{86}Rb		
Phytoplankton				4-8 days	24
Green Algae				4-8 days	24
			^{137}Cs		
Green Algae	3 days			3 days	33
Snail-whole	<12 days				21
Snail-soft parts				~2 days	29
Clam-soft parts				~15 days	25
Crayfish-muscle	>100 days				35
Crayfish-whole	~100 days				35
Fish-muscle				~16 days	29
Fish-whole		40 days			32
Fish-whole		175-200 days			8
Fish-whole		55-100 days			8
Fish-whole		25-80 days			8
Fish-whole	47.2 days	47.4 days			20
			^{45}Ca		
Tubificid worm		2.5 hrs.		2 days	45

*Specific activity= μCi radionuclide/g total element.

**Section .

CONTINUED

TABLE 37. RADIONUCLIDE HALF-TIMES, SPECIFIC ACTIVITIES*, AND EQUILIBRATION TIMES IN BIOLOGICAL MATERIALS - LITERATURE VALUES

Sample Type	Effective $T_{1/2}$	Biological $T_{1/2}$	Specific Activity	Time to equilibrium	Ref.**
		^{65}Zn			
Phytoplankton				4-8 days	24
Green Algae				4-8 days	24
Green Algae	~2 days				33
Snail-soft parts				~4 days	29
Clam-soft parts		1500 days	250		2
Fish-muscle				~24 days	29
Fish-whole	134 days			~70 days	5
		^{90}Sr			
Green Algae	~8 hrs				33
Green Algae				~10 days	48
Green Algae	~10 days				
Aquatic plants				2 days	44
Tubificid worm		3 hrs			
Snail-soft parts				~4 days	29
Clam-soft parts				30-40 days	25
Clam-shell				~30 days	34
Clam-shell			1.67 to 311		32

*Specific activity = μCi radionuclide/g total element.

**Section

CONTINUED

TABLE 37. RADIONUCLIDE HALF-TIMES, SPECIFIC ACTIVITIES*, AND EQUILIBRATION TIMES IN BIOLOGICAL MATERIALS - LITERATURE VALUES

Sample Type	Effective T½	Biological T½	Specific Activity	Time to equilibrium	Ref.**
			^{32}P (Continued)		
Backswimmers (*Notonecta*)				8 days	28
Diving beetle (*Dytiscus*)				30 days	28
Water strider (*Gerris*)				30 days	28
				30 days	34
Clam-soft parts				20-30 days	25
Clam-soft parts				30-40 days	16
Fish-whole					23
Fish-whole			0.5		
			^{54}Mn		
Clam-soft parts		3100 days	25		2
Clam-soft parts			3000		17
			^{59}Fe		
Phytoplankton				4-8 days	24
Green Algae				4-8 days	24
Fish-whole	43.1 days	978 days			19

*Specific activity = μCi radionuclide/g total element.

**Section

CONTINUED

TABLE 37 . RADIONUCLIDE HALF-TIMES, SPECIFIC ACTIVITIES,* AND EQUILIBRATION TIMES IN BIOLOGICAL MATERIALS - LITERATURE VALUES

Sample Type	Effective T½	Biological T½	Specific Activity	Time to equilibrium	Ref.**
		^{55}Fe			
Fish-whole	512 days				19
		^{106}Ru			
Snail-whole	<12 days				21
		^{60}Co			
Phytoplankton				4-8 days	24
Green Algae				4-8 days	24
Snail-soft parts				~2 days	29
Crayfish-whole		~23-70 days			15
Fish-msucle		~24 days			29
		^{144}Ce			
Snail-whole	<12 days				21
		^{131}I			
Fish-blood plasma	1.4 days	1.7 days			22
Fish-head		9-37 days			55

*Specific activity = µCi radionuclide/g total element.

**Section

CONTINUED

TABLE 37. RADIONUCLIDE HALF-TIMES, SPECIFIC ACTIVITIES*, AND EQUILIBRATION TIMES IN BIOLOGICAL MATERIALS - LITERATURE VALUES

Sample Type	Effective $T_{1/2}$	Biological $T_{1/2}$	Specific Activity	Time to equlibirium	Ref.**
		^{90}Sr			
Fish-msucle		12-48 min			13
Fish-muscle				~24 days	29
Fish-msucle		<1 hr			32
Fish-msucle				72 days	37
Fish-bone				5 yrs	30
		^{51}Cr			
Marine clam-muscle	27 days				4
		^{32}P			
Plankton				6-12 hrs	28
Green Algae				2-4 hrs	28
Green Algae				3 hrs	31
Chironomid-larvae			4		23
Caddisfly-larvae (*Hydopsyche*)		16 hrs			23
Mayfly-nymph (*Callibaetis*)				4 days	28
Dragonfly-nymph (*Sympetrum*)				16 days	28

*Specific activity = μCi radionuclide/g total element.

**Section

RECOMMENDATIONS FOR FURTHER STUDIES

1) A systematic program for the sampling of water and suspended solids should be established to correlate elemental concentrations with stream and river flow characteristics within limited watersheds.

2) In addition to elemental composition, the adsorption capacities of suspended solids for significant radionuclides should be established.

   A detailed comparison of characteristics of river sediments with local rocks and sedimentary materials from which they were derived should be made. Of special interest are those characteristics that lead to differences in cation exchange capacity.

   Determine by sampling or inference the ultimate fate of particulates high in cation exchange capacity, and determine the factors which may cause the apparent annual cycle of cation exchange capacities of river sediments.

3) In order to make detailed statistical comparisons within and between species from selected watersheds, studies on the inherent variability of trace elements should be made.

4) Detailed studies of the food web interrelationships within the freshwater ecosystem should be made in order to provide data on energy transfer.

5) Laboratory and simulated field studies are required on the rates of accumulation and loss of the significant radionuclides by the major food organisms as a function of age, growth and stable element composition.

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REFERENCES

Agnedal, P. O. 1967. Calcium and strontium in Swedish waters and fish accumulation of ^{90}Sr. In "Radioecological Concentration Processes" p. 879-896. Pergamon Press, New York.

Amphlett, C. B. 1963. Treatment and disposal of radioactive wastes. Pergamon Press, New York. 289 p.

Bearr, F. Ed. 1964. "Chemistry of the Soil". 2nd Ed. Reinhold Publishing Co., New York. p. 485-489.

Bennett, C. F. 1962. The Bayano Cuna Indians, Panama: An Ecological Study of Livelihood and Diet. Annals. Assoc. Amer. Geog. 52, no. 1.

Bowen, H. J. M. 1966. Trace elements in biochemistry. Academic Press. London. 241 p.

Breder, C. M. Jr. 1927. The fishes of the Rio Chucunaque drainage, eastern Panama. Bull. Am. Mus. Nat. Hist. 62:91-176.

Causert, J. 1962. "Fish as a source of Mineral Nutrition" In "Fish as Food", G. Borgstrom, Ed., Academic Press, New York. p. 206-230.

Charnell, R. 1968. Personal Communication.

Cushing, C. E. 1963. Hanford Research Annual Report HO-500. p. 212-218.

Dahl, G. 1961. Los peces fluviales del Choco. In Plan de fomento regional para el Choco 1959-1968, Dept. Admin. Planeacion y Serv. Tec., Cali, Colombia.

Darlington, P. J. Jr. 1957. Zoogeography: the geographical distribution of animals. Wiley and Sons, New York. 675 p.

Eigenmann, C. H. 1922. The fishes of western South America. Part I. Mem. Carnegie Mus. 9:1-350.

Foreman, E. E., K. W. E. Bidwell. 1957. A biological investigation of the fate of strontium-90 in a disused filter bed. UKAEA Report IGR/TN. W. 659.

Gibbs, R. J. 1965. The geochemistry of the Amazon River basin (Ph.D. Thesis) Univ. of Cal., San Diego. Diss. Abst. #65-14,513.

Hevesy, G., D. Lockner, K. Sletter. 1964. Iron metabolism and erythrocyte formation in fish. Acta Physiol. Scand. 60:256-26.

Hildebrand, S. F. 1938. A new catalogue of the fresh-water fishes of Panama. Filed Mus. Nat. Hist., Zool. Ser. 22:219-359.

Kharker, D. P., K. K. Turekian, K. K. Bertine. 1967. Trace element levels in water. Geochim. Cosmochim Acta. (In Press).

Kolehmainen, S., E. Hasanen and J. K. Miettinen. 1967. ^{137}Cs in fish, plankton and plants in Finnish Lakes during 1964-65. In "Radio-ecological Concentration Processes". p. 913-919. Pergamon Press, New York.

Livingstone, D. A. 1963. Chemical composition of rivers and lakes. Data of geochemistry, 6th Ed. Chapter G. U. S. Govt. Printing Office.

Loftin, H. 1965. The geographical distribution of the freshwater fishes in Panama. (Ph.D. Thesis) Florida State University, Diss. Abstr. #66-2095.

Lowhammer, G. 1938. Wasserchemie and Höhere vegetation Schwedischer. San. Symb. Bot. Upsaliens. 111, 1.

Lowman, F. G. 1966. Progress summary report No. 4. Puerto Rico Nuclear Center, Marine Biology Program, PRNC #85.

Meek, S. E. and S. F. Hildebrand. 1916. The fishes of the fresh waters of Panama. Field Mus. Nat. Hist., Zool. Ser. 10:217-373.

Miles, C. 1947. Los peces del Rio Magdalena. Min. Econ. Nac., Sec. Piscicult., Bogota. 214 p.

Miller, R. R. 1966. Geographical distribution of Central American freshwater fishes. Copeia 1966:773-802.

Myers, G. S. 1938. Fresh-water fishes and West Indian zoogeography. Smiths. Rept. for 1937:339-364.

Nelson, D. J. 1967. The prediction of ^{90}Sr uptake in fish using data on specific activities and biological half-lives. In "Radioecological Concentration Processes". p. 843-852. Pergamon Press, New York.

Phillips, A. M. Sr., F. E. Lovelace, D. R. Brockway, D. J. Bolzer Jr. 1952. The calcium, magnesium and phosphorous content of small brook trout. Fisheries Res. Bull. #16. The nutrition of trout, Cortland Hatchery Report #21 for the year 1952. p. 44.

Preston, A., D. F. Jefferies, J. W. R. Dutton. 1967. The concentrations of caesium-137 and strontium-90 in the flesh of brown trout taken from rivers and lakes in the British Isles between 1961 and 1966. The variables determining the concentrations and their use in radiological assessments. Water. Res. (1):475-496.

Polikarpov, G. G. 1966. Radioecology of Aquatic Organisms. Rhienhold, New York. 314 p.

Reed, J. R., D. J. Nelson, N. A. Griffith. 1967. Uptake and metabolism of strontium in bluegill flesh and blood. Health Physics Div. Ann. Prog. Report. July 31, 1967. ORNL-4168. p. 93.

Robertson, D. E. 1968. Role of contamination and trace elements analysis of sea water. J. of Anal. Chem. 40:1067-1072.

Silker, W. B. 1964. Variations in elemental concentrations in the Columbia River. Limnol. and Oceanog. 9:540-545.

Spector, W. S., Ed. 1956. "Handbook of Biological Data". W. B. Saunders Co., Philadelphia. p. 72.

Templeton, W. L. 1964. (Unpublished Data).

Templeton, W. L., V. M. Brown. 1964. The relationship between the concentrations of calcium, strontium and strontium-90 in wild brown trout, Salmo trutta L. and the concentrations of the stable element in some waters of the United Kingdom, and the implications in Radiological Health Studies. Air and Water Poll. Int. 8:49-75.

Templeton, W. L., A. Preston. 1966. Transport and distribution of radioactive elements in coastal and estuarine waters of the United Kingdom. Proceedings of the Sympsoium on the Disposal of Radioactive Wastes into Seas, Oceans and Surface Waters. IAEA Vienna (16-20 May, 1966).

Thompson, R. C., J. E. Ballou. 1956. Studies of metabolic turnover with Tritium as a tracer. V. The predominantely non-dynamic state of body constituents in the rat. J. Biol. Chem. 223:795.

Turekian, K. K., M. R. Scott. 1967. Concentrations of Cr, Ag, Mo, Ni, Co, and Mn in suspended material in streams. Environ. Sci. and Tech. Vol. 1(1):940-42.

Vinogradov, A. P. 1953. The elementary chemical composition of marine organisms. Sears Foundation for Marine Research. Mem. No. 2. p. 510.

Viswanathan, R., Y. M. Bhatt, J. R. Naidu, G. R. Doshi, C. Kannan Unni. 1962. Mineral content of freshwater and freshwater organisms. AEET/HP/BS-1.

Viswanathan, R., Y. M. Bhatt, C. Sreekumaran, G. R. Doshi, S. S. Gogate, A. M. Bhagwat and C. K. Unni. 1966. Mineral content of aquatic foods. Proc. of Ind. Acad. of Sci. Vol. LXIV. No. 6. Sec. B. p. 301-313.

Welcher, F. J., Ed. 1966. Standard methods of chemical analysis. Vol. 3. Part B. 6th Ed. D. Van Nostrand. P. 1867.

Wilson, D. O., J. F. Cline. 1966. Removal of plutonium-239, tungsten-185 and lead-210 from soils. Nature 209:941-42.