Annual Report
ENV

REPORT No.
N R L - F/43

DEPARTMENT OF HEALTH

ENVIRONMENTAL RADIOACTIVITY IN NEW ZEALAND

AND

PACIFIC AREA MONITORING

ANNUAL SUMMARY

1970

P
ENV

NATIONAL RADIATION LABORATORY
P.O. BOX 1456, CHRISTCHURCH, NEW ZEALAND

SYMBOLS, UNITS, AND EQUIVALENTS

UNITS OF RADIOACTIVITY

Ci	Curie	3.7×10^{10}	disintegrations per second
mCi	millicurie	10^{-3} Curies	
pCi	picocurie	10^{-12} Curies	2.22 disintegrations per minute

UNITS OF LENGTH, AREA, VOLUME AND MASS AND THEIR EQUIVALENTS IN THE IMPERIAL SYSTEM

cm_2..	centimetre	0.394 inches
km^2..	square kilometre	0.386 square miles
m^3	cubic metre..	35.31 cubic feet
litre	litre	0.880 quart
g	gram	0.0353 ounce

NOTES

1. Unless otherwise noted, all times given in this report are New Zealand Standard time i.e. G.M.T. + 12 hours.

2. Radioactive fallout in rain is expressed as:

   (a) Deposition - millicuries per square kilometre (mCi/km^2)

   (b) Concentration - picocuries per litre (pCi/litre)

   $$\text{Concentration (pCi/litre)} = \frac{\text{deposition } (mCi/km^2)}{\text{rainfall (cm)}} \times 100$$

   Multiply mCi/km^2 by 2.59 to obtain mCi/sq. mile.

3. The levels of strontium-90 contamination in food and bone are given in "Strontium Units" i.e. picocuries strontium-90 per gram of calcium .....pCi Sr^{90}/g Ca.

   Similarly caesium-137 results are given as picocuries of caesium-137 per gram of potassium.....pCi Cs^{137}/g K.

   One litre of whole milk contains approximately: 1.2 g of calcium
   1.4 g of potassium

C O N T E N T S

POTENTIAL HEALTH HAZARDS

There are no internationally accepted levels for the exposure of people to fallout from nuclear weapons testing. Most of the measurements recorded in this report concern such contamination and it is considered necessary in the public interest to provide some guide by which the significance of the values may be appreciated.

The simplest procedure is to compare the measured radioactive concentrations with those which are calculated to give exposures related to the Dose Limits suggested by the International Commission on Radiological Protection. These annual Dose Limits are one tenth of the annual Maximum Permissible Doses for radiation workers and were established to provide standards for the design and operation of radiation sources in order that the risks to members of the public should be no greater than other risks regularly accepted in every day life. The Commission emphasises that all controlled radiation exposures should be kept to the minimum practicable and that the risks should be justified in terms of benefits that would not otherwise be received.

The following concentration reference levels have been derived which are in no case greater than one third of the concentrations which, if maintained indefinitely, would individually lead to the Dose Limits. In setting these reference concentrations, allowance has been made for the risk to children. The media and radionuclides listed are those generally accepted as the key items for monitoring fallout contamination and the units of concentration are those used in the reports of this Laboratory.

Reference Concentration Levels

In Milk:

Strontium-90	270	pCi/g Ca
Caesium-137	7,000	pCi/g K
Iodine-131	200	pCi/litre

In Air:

Mixed fission products between 10 and 80 days old.	300	pCi/cubic metre

In Rainwater:

Mixed fission products between 10 and 80 days old.	6,000	pCi/litre

(continued)

For those concentrations which can change rapidly with time, such as mixed fission products in air or in rain, or Iodine-131 in milk, occasional transient values may greatly exceed the reference levels. The average concentrations over a year, however, should be compared with the reference levels.

COMPARISON OF REFERENCE LEVELS WITH NATURAL RADIATION BACKGROUND

The long term hazards of fallout radiation are best understood by comparison with the levels of background radiation to which the human race has always been exposed. Natural background radiation varies widely in different parts of the world, ranging from a fraction of the "average" to many times the "average" background.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) in its latest (1969) report assessed the effect of all nuclear tests carried out before 1968 on the population of the temperate zone in the Southern Hemisphere. They conclude that the dose received from fallout up to the year 2000 would, in its production of hereditary effects, bone tumours, and leukaemias be equal to that caused by a doubling of the "average" natural radiation background for a period of 5, 8, and 7 months respectively. For the population of the Northern temperate zone the corresponding doses are between 3.3 and 3.6 times higher, while the corresponding figures for the whole world population are 11, 26 and 18 months respectively.

Stratospheric fallout levels are highest in the temperate zones of both hemispheres and decrease markedly towards the equator. Tropospheric fallout levels, however, tend to be higher at latitudes close to the latitude of injection. Global fallout levels, used as the basis of the UNSCEAR assessment, are averages which may differ significantly from levels at individual locations. In the present report radiation levels at individual locations are stated in terms directly related to the reference levels listed.

If the reference levels listed above were maintained indefinitely, they would each lead to a dose rate of the order of that received from the natural background radiation. Therefore, those genetic and somatic effects which can be attributed to the natural background radiation could be expected to increase in proportion.

GENERAL STATEMENT OF RESULTS ON RADIOACTIVE FALLOUT

The pattern of the increases in radioactive fallout resulting from the French nuclear tests in the South Pacific during 1970 was similar to that observed during the previous test series in 1966-1968. In general the levels of radioactivity in air and rainwater were somewhat lower than those in 1968. At New Zealand stations the levels in air and the levels of iodine-131 in milk samples were about the same as those in 1968. There have been indications that traces of fission products produced in one or both of the nuclear explosions of 3 and 7 August were transported in a westerly direction causing an increase in air and rainwater radioactivity and iodine-131 levels in milk at Samoa in mid August. A similar westerly excursion probably occurred after one or both of the tests of 23 and 31 May, as indicated by the presence of young fission products in samples collected in New Zealand early in June.

Environmental levels of strontium-90 and caesium-137 reached their highest values in 1964 and 1965 as a result of delayed stratospheric fallout from the U.S.S.R. and U.S.A. tests of 1961 and 1962. Levels then fell steadily to a minimum in 1968. The rate of decline, however, has been halted by the French nuclear tests in recent years and levels have increased slightly during 1969 and 1970, although still remaining significantly below the peak values in 1964 and 1965.

The levels of environmental radioactivity measured and reported by our monitoring service do not constitute a public health hazard.

SECTION A - MONITORING PROCEDURES

GENERAL INFORMATION

In September 1957 the New Zealand Department of Health was charged, under a Cabinet directive, with the responsibility for monitoring environmental radioactive contamination in New Zealand and the Pacific areas with which it is associated. Subsequently the network of collecting stations shown in Fig. 1 a and b was established to provide the necessary samples of air, rainwater, soil, milk, cattle thyroid, and human bone.

The selection of rainwater collecting stations in New Zealand was based on the requirement that an adequate geographical coverage of the country must be made, taking account of natural features, such as mountain ranges which, particularly in the South Island, account for the extremes in rainfall. Furthermore, proximity of rainwater collecting sites to milk producing areas is desirable, so that comparisons between levels of contamination in rain and milk can be made.

The selection of milk producing areas was based not only on geographical coverage and routine availability of samples but also on population distribution, so that the average result of all stations would be representative of the contamination in the average New Zealand diet.

The results of measurements are published in a series of Quarterly Reports: "Fallout in New Zealand", DXRL-F1 to F9 and NRL-F10 to F18; and "Environmental Radioactivity in New Zealand", NRL-F19 onwards.

During the period of nuclear testing which started in the Christmas Island area in April 1962, the Laboratory's routine monitoring operations were extended within New Zealand, and a new network of monitoring and collection stations was established throughout the Pacific area. The extent of these monitoring operations and the results of measurements were published in previous issues of this series. (See particularly DXRL-F5, DXRL-F7, and DXRL-F8.)

After the conclusion of the 1962 Pacific tests, the monitoring activities of the Laboratory reverted to the established routine pattern. However, during the French series of nuclear tests in the South Pacific, which commenced in July 1966, and were continued in 1967, 1968, and 1970, the monitoring operations of the Laboratory were again extended. The results of these operations during 1966, 1967, and 1968 were given in the Annual Summary Reports NRL-F23, NRL-F28, and NRL-F33 respectively. The results of the 1970 operations are given in this report.

Prior to December 1967 the fourth quarterly results and annual summary were published under one cover. Since then, however, the Annual Summary Report has been published separately. Individual results, therefore, having been tabled in the four preceding quarterly reports, are not given in the Annual Summary.

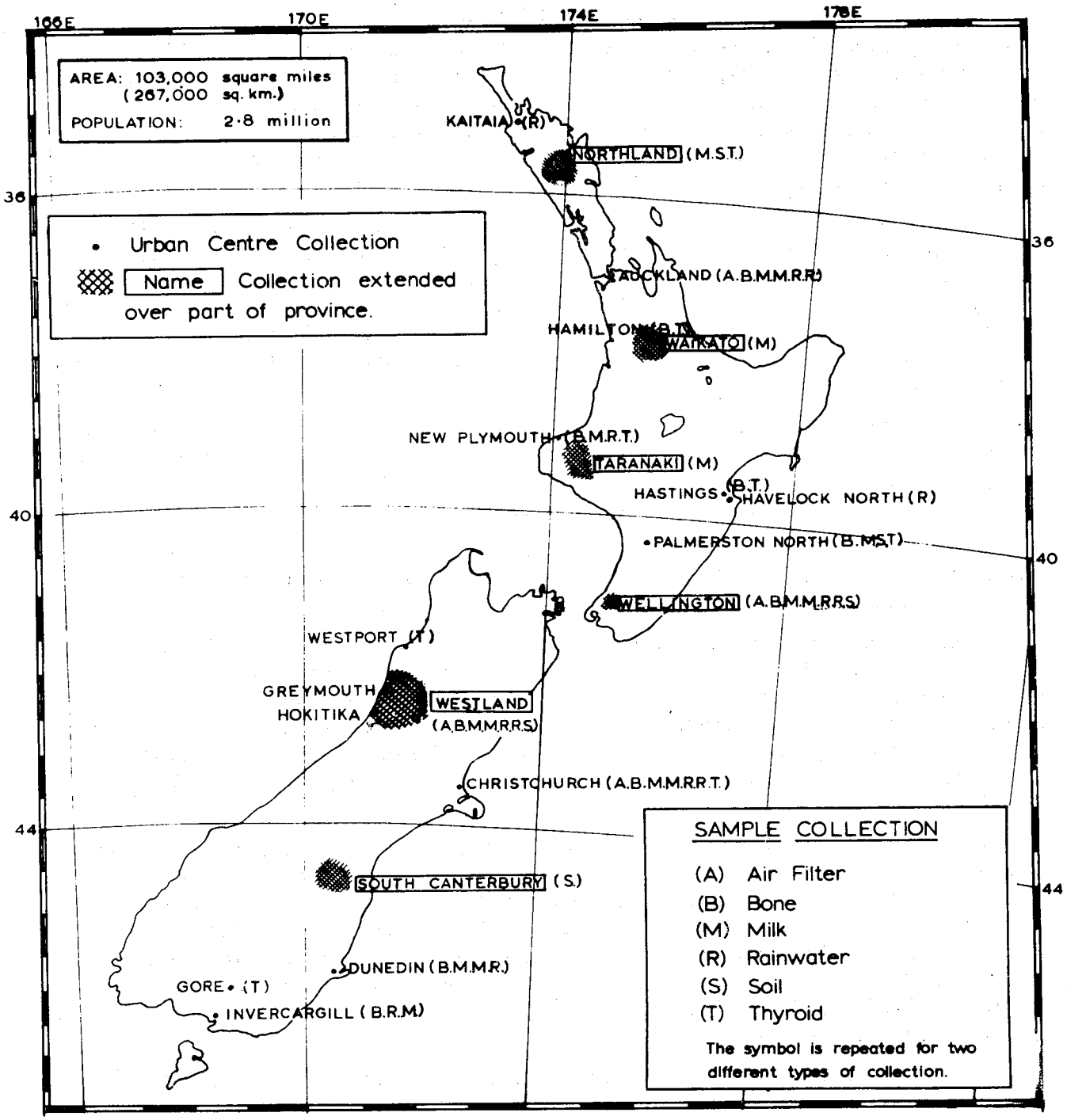
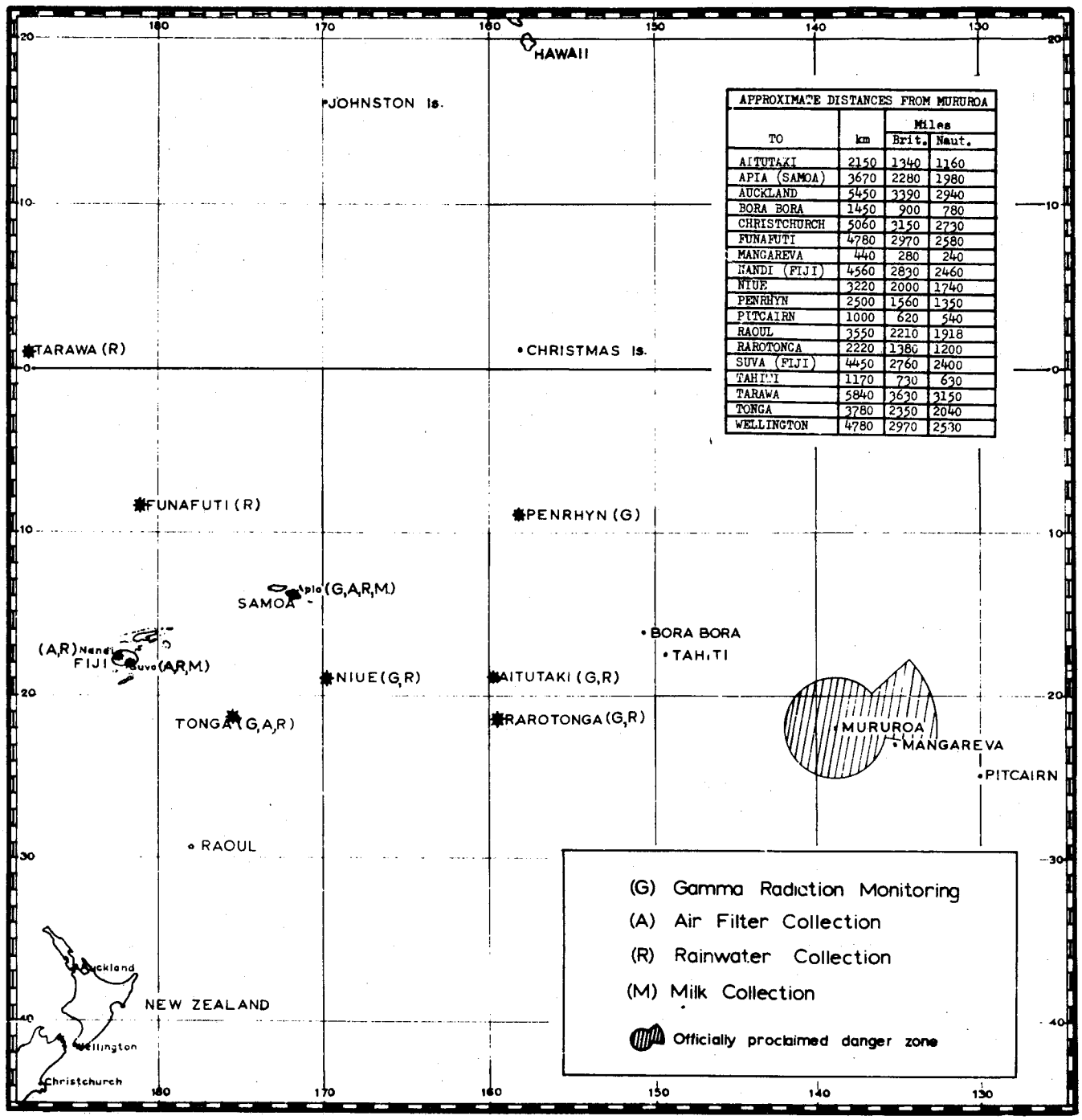


Fig.1a COLLECTING STATIONS IN NEW ZEALAND



APPROXIMATE DISTANCES FROM MURUROA

TO	km	Miles Brit.	Miles Naut.
AITUTAKI	2150	1340	1160
APIA (SAMOA)	3670	2280	1980
AUCKLAND	5450	3390	2940
BORA BORA	1450	900	780
CHRISTCHURCH	5060	3150	2730
FUNAFUTI	4780	2970	2580
MANGAREVA	440	280	240
NANDI (FIJI)	4560	2830	2460
NIUE	3220	2000	1740
PENRHYN	2500	1560	1350
PITCAIRN	1000	620	540
RAOUL	3550	2210	1918
RAROTONGA	2220	1380	1200
SUVA (FIJI)	4450	2760	2400
TAHITI	1170	730	630
TARAWA	5840	3630	3150
TONGA	3780	2350	2040
WELLINGTON	4780	2970	2530

Fig.1b MONITORING AND COLLECTING STATIONS ON PACIFIC ISLANDS

SAMPLING AND MEASURING METHODS

The following information lists the type and extent of sample collection and measurement undertaken by the Laboratory during its routine operations throughout 1970 and also during the extended monitoring programme from 16 May to 31 October 1970. The procedures for radiochemical separations and measurement of radioactivity were described in detail in the Annual Summary for 1966 (NRL-F23) and are only briefly referred to here. The procedures for the measurement of strontium-90 have been modified recently and published. A copy may be obtained from this Laboratory on request.*

1. Portable Gamma Ray Survey Meters

Duplicate sets of gamma radiation monitors were provided on the following 6 Pacific Islands stations for monitoring of the gamma radiation dose rate during the 1970 extended monitoring programme:

Penrhyn	Aitutaki	Rarotonga	Apia (Samoa)	Niue	Tonga

The most sensitive range on these instruments is 0 - 0.5 mR/hr, enabling significant readings to be made even on natural background radiation. Any increase in the gamma radiation dose rate on any of the islands monitored can thus be detected long before it reaches levels indicating a possible health hazard. Gamma radiation dose rate measurements were made several times each day by observers of the New Zealand Meteorological Service concurrently with their meteorological observations. Readings were made at a fixed position 3 feet (91 cm) above the ground. Only readings exceeding 0.3 mR/hr are reported to the Laboratory.

2. Air Sampling (For Measurement of Total Beta Activity)

Air filter samples are collected continually at Auckland, Wellington, Hokitika, and Christchurch. Sampling involves the collection of particulates in ground level air by drawing the air through 11 cm diameter glass fibre filters (Whatman GF/A) using positive displacement pumps. About 100 m^3 of air per day are sampled at all stations except Christchurch where about 300 m^3 per day are sampled. The filters are changed three times each week. During the extended monitoring programme, however, daily air filter samples were collected at the following 8 stations:

NEW ZEALAND		PACIFIC ISLANDS	
Auckland	Hokitika	Nandi (Fiji)	Apia (Samoa)
Wellington	Christchurch	Suva (Fiji)	Tonga

* "The Determination of Radiostrontium in Rainwater, Soil, Milk and Bone." L.P. GREGORY, National Radiation Laboratory, Report No. NRL-RM/3

The air filters are airmailed to Christchurch and the total beta activity of the entire filter is measured using a 5 inch beta detector. Measurement is made four days after the end of collection to allow for the decay of natural atmospheric radioactivity.

3. Rainwater

(1) Monthly Collection (For Measurement of Strontium-90, Strontium-89 and Lead-210.) Rainwater is collected by exposing a stainless steel pot of 30cm diameter and 30cm height, at ground level, each month at each of the following 11 collecting sites:

Site	Annual Rainfall (1970) cm	Site	Annual Rainfall (1970) cm
New Zealand		New Zealand	
Kaitaia	117	Christchurch	57
Auckland	115	Dunedin	53
New Plymouth	159	Invercargill	96
Havelock Nth	67		
Wellington	123	Pacific Islands	
Greymouth	238	Suva, Fiji	299
		Rarotonga	186

The appropriate carriers are added to the collecting pots before despatch to the collecting sites. A supply of distilled water is maintained at the site and is added to the pot when necessary to prevent the contents from evaporating to dryness during dry periods. On arrival at the Laboratory the carriers are separated by ion exchange elution chromatography. Strontium-89 is determined by beta counting the separated strontium source. Strontium-90 is determined by measurement of its daughter Yttrium-90 and Lead-210 by measurement of its daughter Bismuth-210.

(2) Weekly Collection (For Measurement of Total Beta Activity)

Samples of rainwater, collected each week by means of a polythene funnel and bottle collector from the four New Zealand stations listed below, are returned to the Laboratory for processing and measurement of total beta activity. During the extended monitoring programme, however, weekly samples were also obtained from the nine Pacific Island stations listed.

New Zealand	Pacific Islands		
Auckland	Tarawa	Suva (Fiji)	Tonga
Wellington	Funafuti	Apia (Samoa)	Aitutaki
Greymouth	Nandi (Fiji)	Niue	Rarotonga
Christchurch			

The collecting bottles contain carrier solution for fission products, and the funnels have a diameter of 17.0 cm at New Zealand stations and 9.9 cm at Pacific Island stations. The collected rainwater samples are evaporated to dryness and counted in 4.5 inch planchettes using a 5 inch beta detector.

4. Milk

(1) Monthly Collection (For Measurement of Strontium-90 and Caesium-137)

Composite milk samples are obtained in New Zealand each month from the following 9 urban centres or provinces:

Northland	Taranaki	Westland
Auckland	Palmerston North	Christchurch
Waikato	Wellington	Dunedin

Dried milk samples are obtained whenever possible. Liquid milk samples are dried and powdered before measurement. Caesium-137 and potassium-40 are measured by gamma spectrometry. The monthly samples are then aggregated on a quarterly basis for each station for ashing and measurement of strontium-90. Strontium carrier is separated from other milk ash constituents with nitric acid followed by ion exchange elution chromatography. Strontium-90 is then determined by measurement of its daughter Yttrium-90.

(2) Special Collection (For Measurement of Iodine-131)

During the period of extended monitoring, representative samples of fresh milk were despatched to Christchurch on Mondays, Wednesdays and Fridays of each week from the following 7 New Zealand town milk supplies:

Auckland	New Plymouth	Wellington	Greymouth	Christchurch	Dunedin	Invercargill

Thrice weekly collections were also obtained at

Suva (Fiji)	Apia (Samoa)

Iodine-131 was separated from fresh milk by absorption on anion exchange resin and measured by gamma spectrometry of the resin. At the two Pacific Island Stations the separation was made locally and the resin was airmailed to Christchurch for measurement.

5. Cattle Thyroids (For Measurement of Iodine-131)

During the extended monitoring programme, sampling of cattle thyroids was undertaken once each week at the following 8 stations:

Northland (Moerewa)	Palmerston North (Longburn)
Hamilton (Horotiu)	Westport
New Plymouth (Waitara)	Christchurch (Islington)
Hastings (Tomoana)	Gore

Radioiodine was measured by gamma spectrometry of the thyroids.

6. Human Bone (For Measurement of Strontium-90, Radium-226 and Lead-210)

Post mortem samples of human bone are obtained whenever possible. Samples have been collected at Auckland, Hamilton, Hastings, Napier, New Plymouth, Palmerston North, Wellington, Nelson, Greymouth, Christchurch, Dunedin, Invercargill, and from some provincial areas.

7. Soil (For Measurement of Strontium-90)

Soil is sampled annually from the following 4 districts: Northland, Wellington, Greymouth and South Canterbury. Samples were taken at Campbell Island (52.5°S 169.0°E) up to February 1965.

SECTION B - MONITORING RESULTS

NUCLEAR TESTS IN THE SOUTH PACIFIC

From 16 May to 7 August 1970 eight nuclear devices were detonated in the atmosphere at islands in the Tuamotu Archipelago. This was France's fourth series of nuclear tests in the South Pacific. The New Zealand programme for monitoring radioactive contamination from these tests commenced on 16 May and continued until 31 October 1970.

Table 1 lists the dates and available information on power or yield of all nuclear tests in the South Pacific since 1966. The periods of this Laboratory's extended monitoring programmes are also listed.

TABLE 1	NUCLEAR TESTS IN THE SOUTH PACIFIC 1966 - 1970		MONITORING PERIOD
1966	3 July	25-30 kiloton	1 July
	20 July	70-80 kiloton	
	12 September	about 120 kiloton	to
	25 September	about 150 kiloton	
	5 October	200-300 kiloton	31 December
1967	6 June	low yield	1 June
	28 June	low yield	to
	3 July	low yield	30 September
1968	8 July	medium power	4 July
	16 July	medium power	
	4 August	medium energy	to
	25 August	Hydrogen Bomb (2 megaton)	
	9 September	Hydrogen Bomb (2 megaton)	30 November
1969	NO NUCLEAR TESTS IN THE PACIFIC		
1970	16 May	low power	16 May
	23 May	low power	
	31 May	high power	
	25 June	low power	to
	4 July	Hydrogen Bomb	
	28 July	low power	
	3 August	low power	
	7 August	low power	31 October

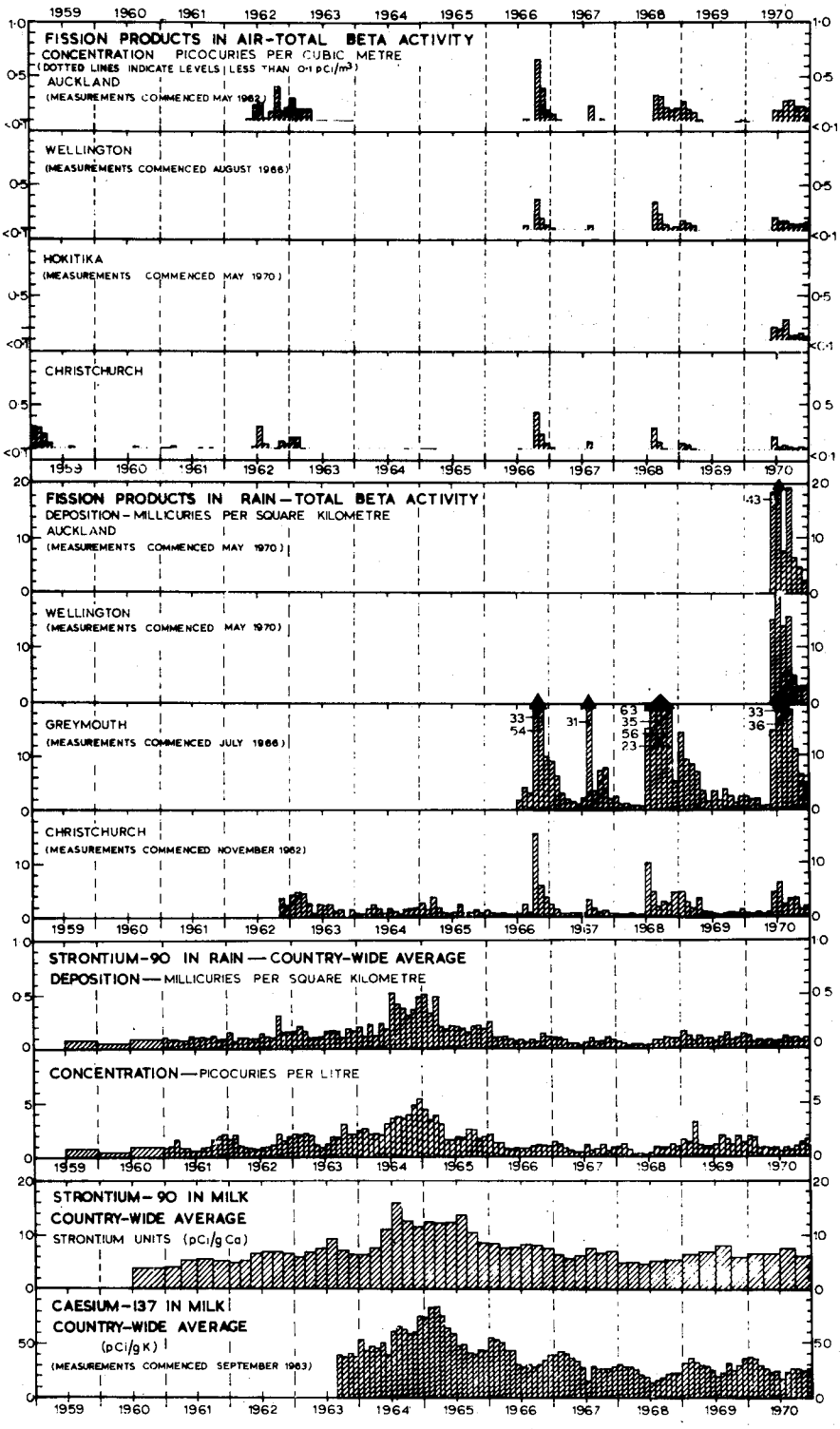


Fig.2 GRAPHICAL SUMMARY OF LONG TERM MEASUREMENTS

GAMMA RAY RADIATION MONITORING

Gamma ray radiation readings have been made several times each day during extended monitoring programmes at six Pacific Island stations. No readings exceeding 0.3 mR/hr (the lowest reporting level set for this monitoring service) have been reported during any of the monitoring periods listed in Table 1.

SUMMARY AND COMPARISON OF RESULTS

1. Fission Products in Air

(1) Routine Measurements at Four New Zealand Stations. In the absence of fresh fission products in the atmosphere, the levels of total beta activity in air are usually less than 0.1 pCi/m^3 (typically about 0.03 pCi/m^3). Over the past decade transient increases in the levels, due to nuclear tests in the atmosphere, have been measured. Most of the radioactivity produced in nuclear explosions is due to short lived fission products and, therefore, radioactive decay causes a progressive reduction in the levels of radioactivity during the months after nuclear tests. Moreover, the scavenging of the atmosphere by rain further reduces the levels in air. In Fig. 2 the average levels for each month are shown for the four New Zealand stations. The increases caused by the U.S. tests in the North Pacific in 1962, and more recently by the French tests in the South Pacific in 1966-1968 and 1970, are apparent. The progressive reduction in the levels after each test series is also apparent although it is significant to note that the rate of decrease was slower following the 1968 tests. This is attributed to the injection of fission products into the stratosphere by the two hydrogen bombs tested for the first time in the French series. After stratospheric injection there is a delay in the transfer of fission products to the troposphere where removal by rain occurs. A similar effect may occur following the recent 1970 tests.

The monthly average levels shown in Fig. 2 have been averaged for each year since 1966, where possible, and are shown in Table 2.

TABLE 2 TOTAL BETA ACTIVITY IN AIR - pCi/m^3 ANNUAL AVERAGES

	1966	1967	1968	1969	1970
Auckland	0.14	0.08	0.12	0.12	0.16
Wellington		0.05	0.10	0.09	0.12
Christchurch	0.11	0.06	0.07	0.07	0.10

(2) Extended Monitoring Programme 1970 - 8 Stations. The results of total beta activity measurement on daily air filter samples are shown in Fig.3. Pre-test daily collections of air filters at the four Pacific Island stations were made from about 23 April to 11 May concurrently with the routine thrice weekly collections at the New Zealand stations. When the first nuclear test of the 1970 series occurred on 16 May daily air filter

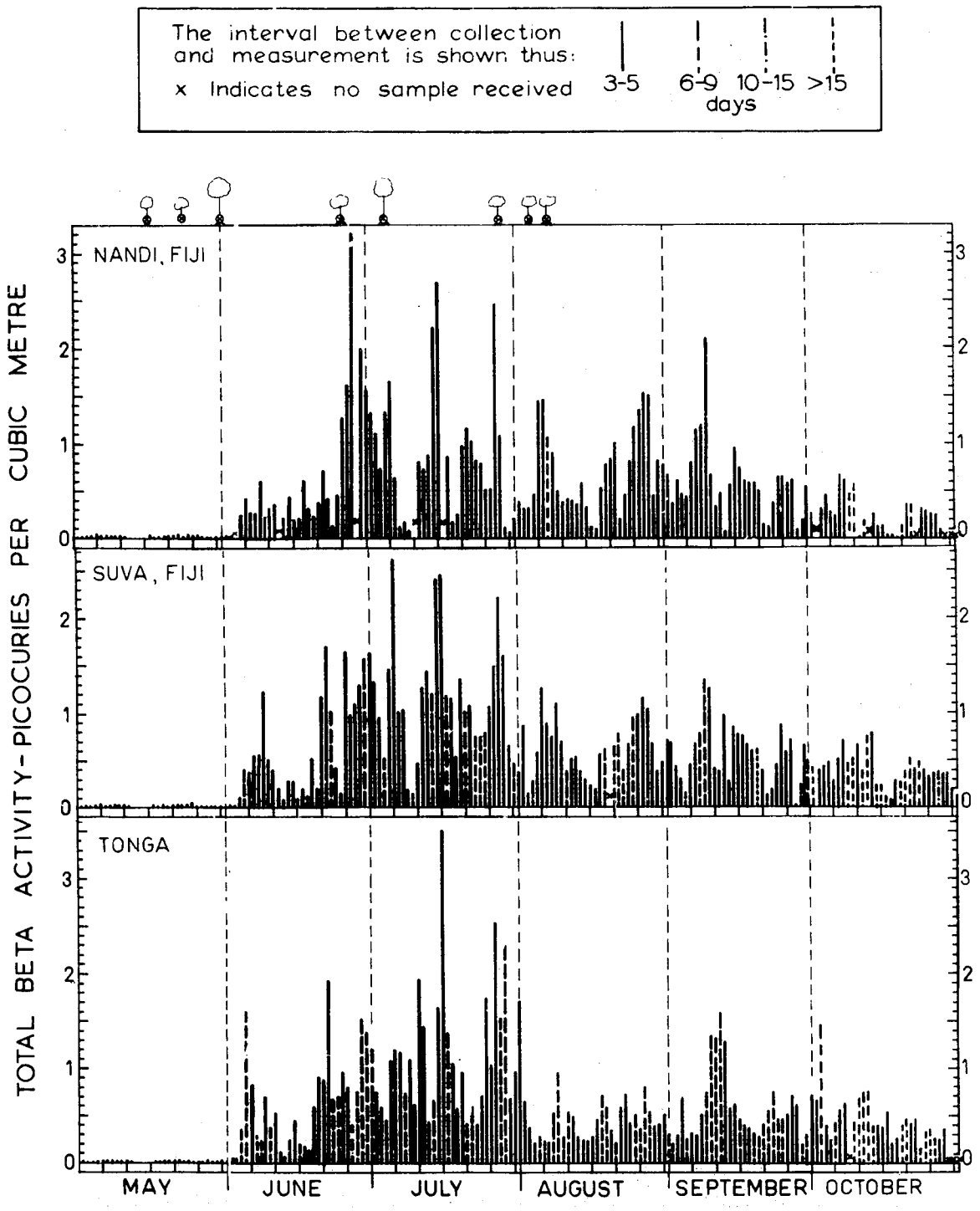


Fig.3 DAILY AIR ACTIVITY DURING 1970 MONITORING PROGRAMME

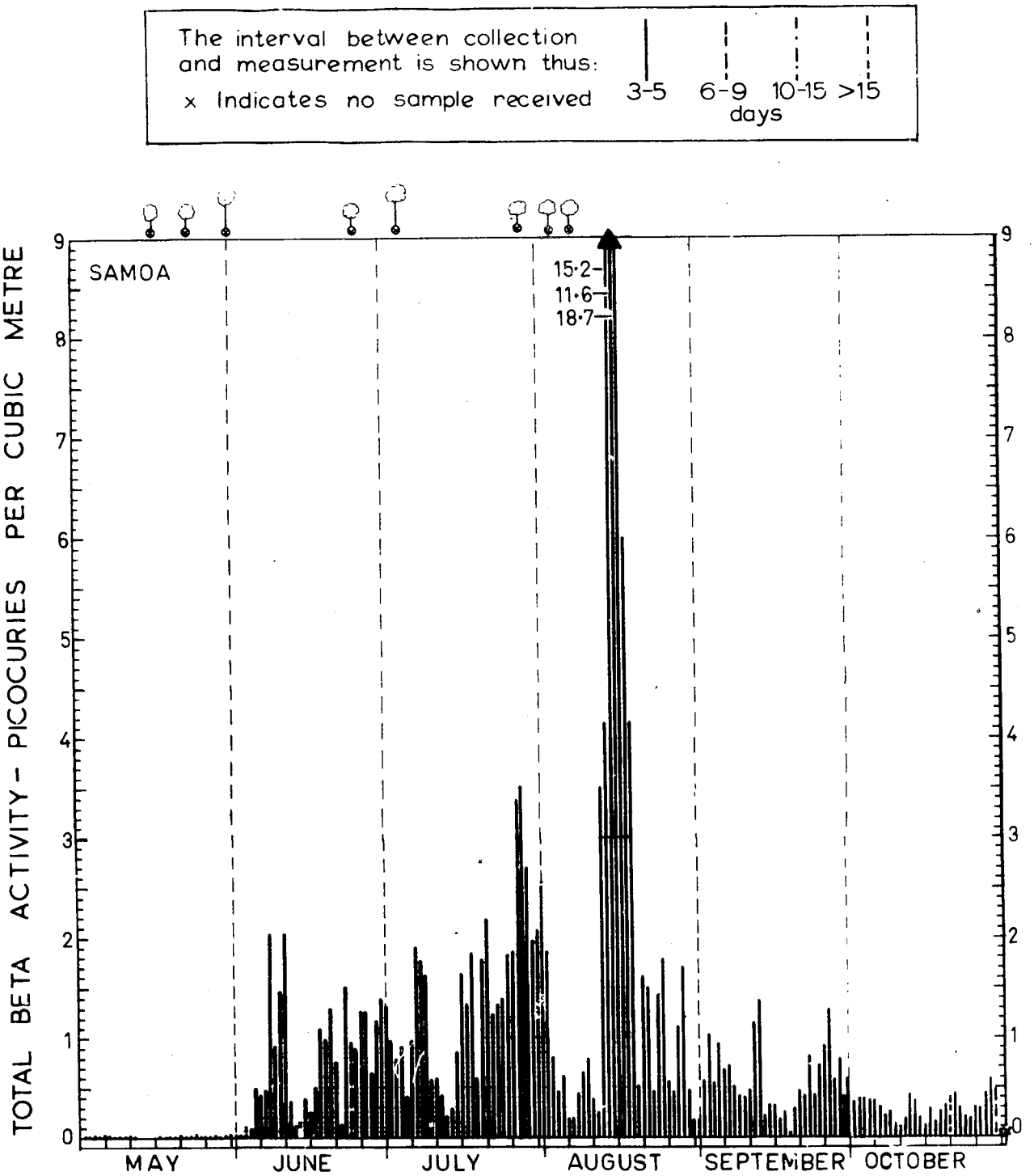


Fig.3 (Continued) DAILY AIR ACTIVITY DURING 1970 MONITORING PROGRAMME

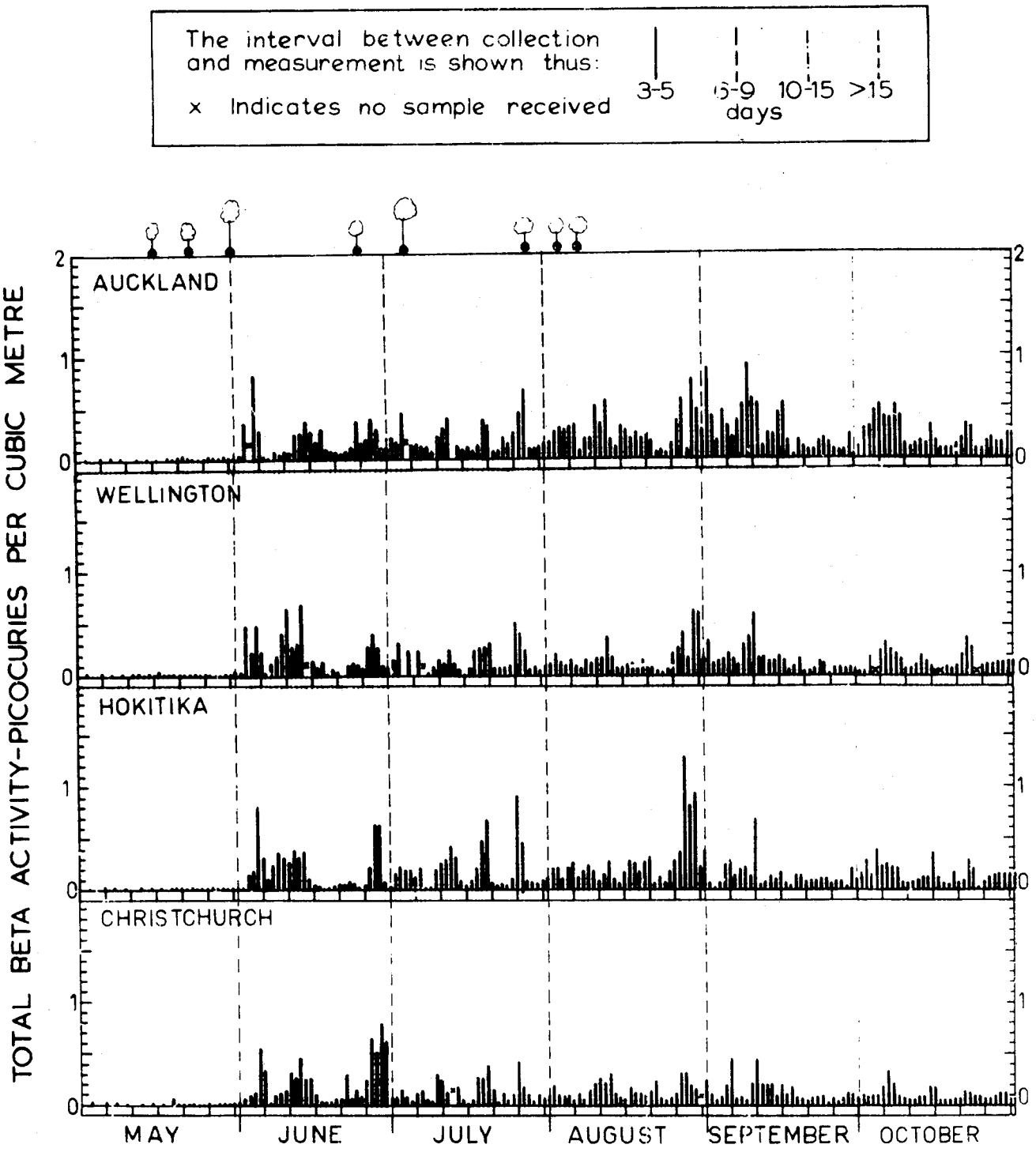


Fig.3 (Continued) DAILY AIR ACTIVITY DURING 1970 MONITORING PROGRAMME

collections commenced at all stations and continued until the end of October. The levels of total beta activity in air filters were low at all stations during April and May (0.01-0.03 pCi/m^3) but increased at all stations between 2 June and 4 June about 18 days after the first nuclear test.

The highest levels were measured on the three air filters collected at Apia, Samoa on 14, 15, and 16 August, a maximum of 18.7 pCi/m^3 being recorded on 16 August. The highest level previously recorded at any of our stations was 73.5 pCi/m^3 at Nandi, Fiji on 17 September 1966.

Measurements of radioactive decay have been made on many samples in order to estimate the age or date of production of the fission products contained in them. The "apparent" age or date of production is derived from an extrapolation of the decay curves with an uncertainty of about $\pm$ 2 days. Radioactive decay measurements on the three highest Samoan filters indicate that the fission products originated in one or both of the nuclear tests of 3 and 7 August. Apparent ages of fission products of 9, 10, and 11 days at collection time were established for the filters collected on 14, 15, and 16 August respectively. These increases of total beta activity in air at Samoa coincide with the increased levels of iodine-131 in milk, and total beta activity in rain collected at Samoa at this time. Moreover, weekly rainwater samples collected at Funafuti and Aitutaki during 10-17 August give apparent ages of fission products of 8 days and 4 days at mid-collection respectively, for these samples. It appears that traces of fresh fission debris were caught in a jet stream and travelled in a westerly direction after one or both of the last two explosions of the 1970 series.

A similar westerly excursion of fission products probably occurred after the second and third tests on 23 and 31 May. Auckland and Wellington air filters collected on 4 June indicate fission products about 9 days old at collection. This is further supported by measurements on weekly rainwater samples collected at Auckland, Wellington, and Greymouth at about this time.

The daily results shown in Fig.3 have been averaged over each month and are listed in Table 3.

TABLE 3 AVERAGE MONTHLY AIR ACTIVITY - pCi/m^3 (1970)							
Pacific Islands	May	June	July	Aug.	Sept.	Oct.	Average 16 May-31 Oct.
Nandi, Fiji	0.03	0.62	0.88	0.70	0.60	0.27	0.56
Suva, Fiji	0.03	0.63	1.13	0.64	0.58	0.40	0.62
Apia, Samoa	0.01	0.84	1.47	2.65	0.59	0.29	1.06
Tonga	0.02	0.64	1.16	0.45	0.59	0.47	0.60
New Zealand							
Auckland	0.02	0.20	0.20	0.28	0.29	0.23	0.22
Wellington	0.02	0.22	0.18	0.18	0.16	0.15	0.16
Hokitika	0.02	0.21	0.20	0.28	0.14	0.15	0.18
Christchurch	0.02	0.23	0.13	0.15	0.13	0.11	0.14

(3) Comparison with Previous Monitoring Programmes. In Fig.4 the average levels of air activity during each month of the French test monitoring programmes since 1966 are shown for each station. The average levels for each entire monitoring period i.e. during nuclear testing and for about three months afterwards, is also of interest for comparison. These are given in Table 4.

TABLE 4 AIR ACTIVITY - pCi/m^3 AVERAGE FOR THE MONITORING PERIOD				
Pacific Islands	1966	1967	1968	1970
Nandi, Fiji	1.39	0.38	0.97	0.56
Suva, Fiji		0.37	1.22	0.62
Apia, Samoa		1.15	1.30	1.06
Tonga			0.81	0.60
New Zealand				
Auckland	0.26	0.11	0.22	0.22
Wellington	0.17	0.07	0.19	0.16
Hokitika				0.18
Christchurch	0.18	0.08	0.14	0.14

These results show that during 1970 the levels were somewhat less in the Pacific Islands than the levels in 1966 and 1968, whereas the levels in New Zealand were about the same. The lower levels in 1967 reflect the smaller number of nuclear devices tested.

(4) Hazard Assessment. Apia, Samoa was again the station with the highest average level (1.06 pCi/m^3) during the 1970 monitoring period. This level is less than 0.4% of the reference level (see Potential Health Hazards page 3).

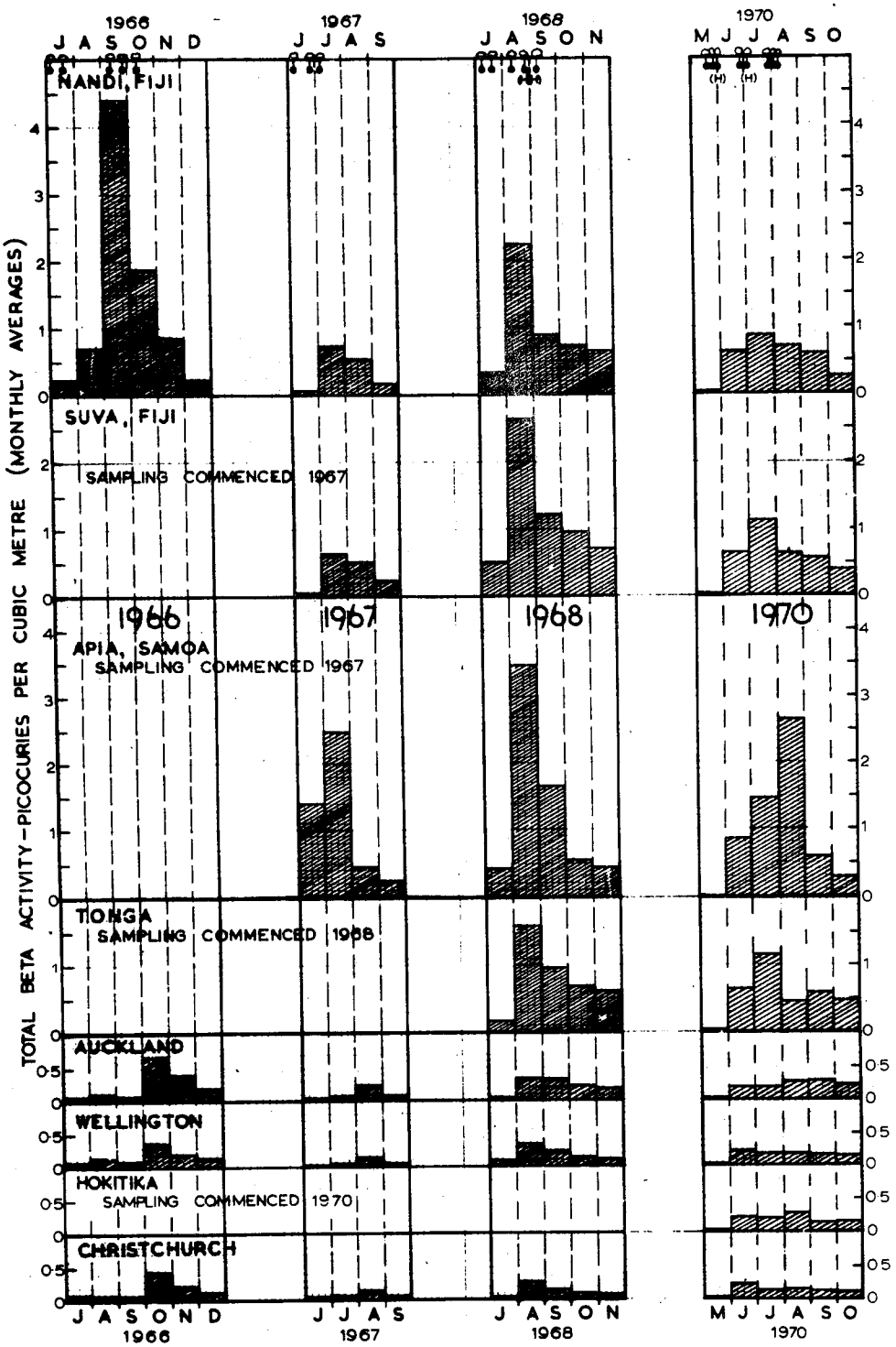


Fig.4 FISSION PRODUCTS IN AIR - COMPARISON FOUR MONITORING PROGRAMMES

2. Fission Products in Rain

(1) Routine Measurements at Four New Zealand Stations. Increases in the levels of fission products in weekly rainwater samples also occurred concurrently with increases in air radioactivity. The weekly depositions of total beta activity at each New Zealand station have been totalled for each month and are shown in Fig.2. The highest level recorded was 43 mCi/km^2 at Auckland during July 1970. The highest level previously recorded was 63 mCi/km^2 at Greymouth during August 1968.

(2) Extended Monitoring Programme 1970 - 13 Stations. During the monitoring period weekly rainwater samples were collected at nine Pacific Island stations in addition to the four New Zealand stations. The results of measurements of total beta activity on these samples is shown in Fig.5 as average daily deposition (at time of measurement). The levels started to increase at most stations during the first half of June. The increase in levels was maintained throughout the monitoring period but had fallen in general by the end of October when this programme finished. The highest average daily depositions were about 4 mCi/km^2 at: Funafuti (22-29 June), Suva (4-11 July), and Greymouth (22-29 August). These levels are a small fraction of the highest level previously recorded - an average of 258 mCi/km^2 per day at Samoa during 13 - 20 September 1966.

It has already been noted under 1.(2) that some rainwater samples collected at Aitutaki, Samoa, and Funafuti contained fission products which probably derived from a westerly excursion of debris after one or both of the nuclear tests of 3 and 7 August. The collection dates of these samples and the apparent production date of the fission products contained in them were:

Aitutaki,	collected	10-17	August.	Production date	(apparent)	9	August
Samoa,	"	15-22	" .	"	"	5	"
Funafuti,	"	10-17	" .	"	"	5	"

Similarly, rainwater samples collected at Auckland, Wellington, and Greymouth during the week ending 5 or 6 June contained fission products deriving from one or both of the tests of 23 and 31 May:

Auckland,	collected	29 May-5	June.	Production date	(apparent)	28	May
Wellington,	"	29 May-5	June.	"	"	31	"
Greymouth,	"	30 May-6	June.	"	"	25	"

(3) Comparison with Previous Monitoring Programmes and Hazard Assessment. Fig.6 shows a comparison of the fission product levels in rain during the four monitoring programmes since 1966.

Table 5 compares the average concentration of fission products in rainwater during each monitoring period since 1966 for selected stations. The hazard assessment is derived by comparing the average level during the monitoring period with the reference level for fission products between 10 and 80 days old. The station selected is the one of highest fallout or one typical of stations with higher levels.

TOTAL BETA ACTIVITIES AT TIME OF MEASUREMENT

The results are expressed as average daily deposition during the collection periods shown.

THE INTERVAL IN DAYS BETWEEN END OF COLLECTION AND MEASUREMENT IS SHOWN AT THE TOP OF EACH COLUMN.

N.S. NO SAMPLE

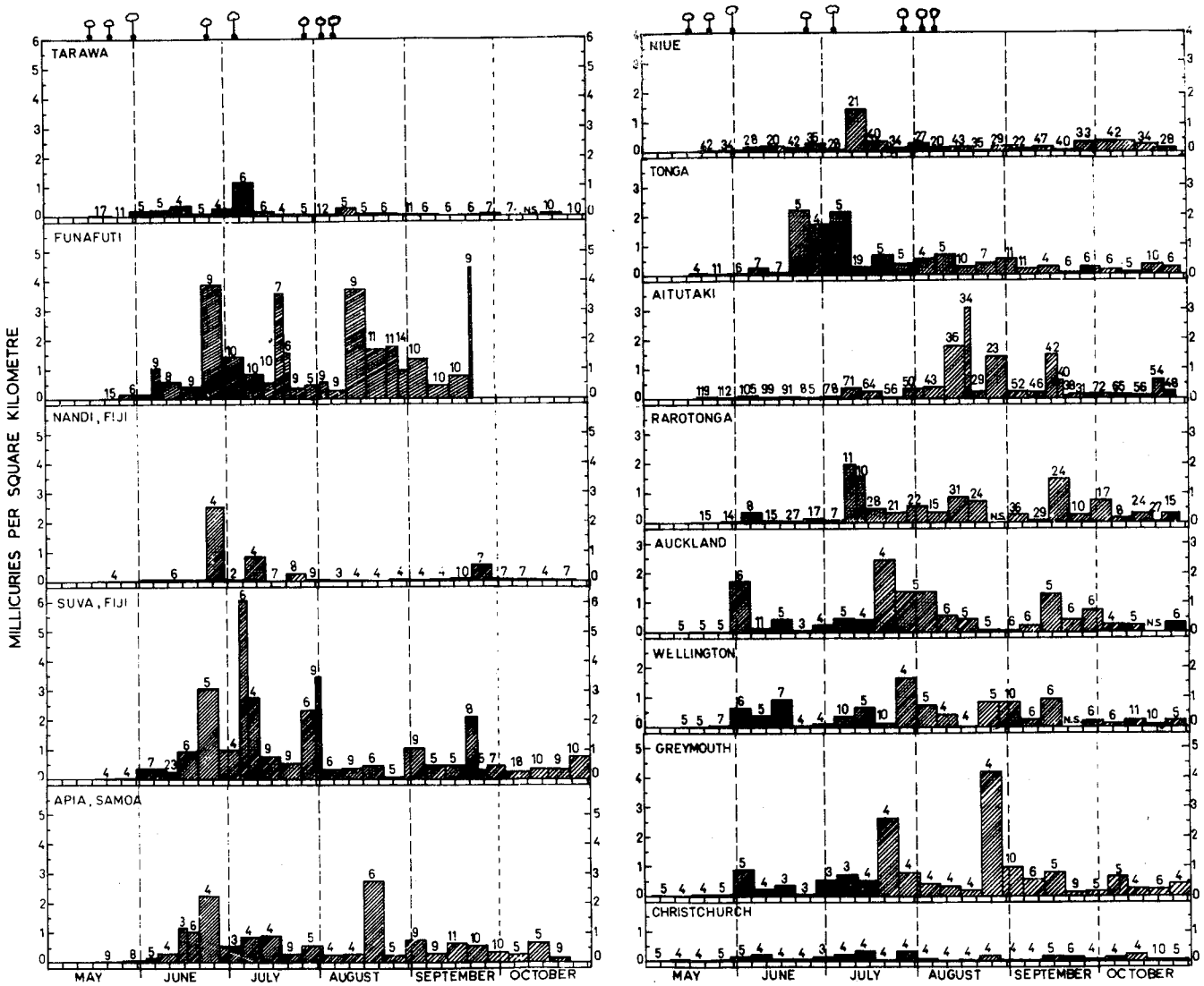


Fig.5 AVERAGE DAILY DEPOSITION OF FISSION PRODUCTS IN RAIN DURING 1970 MONITORING PROGRAMME

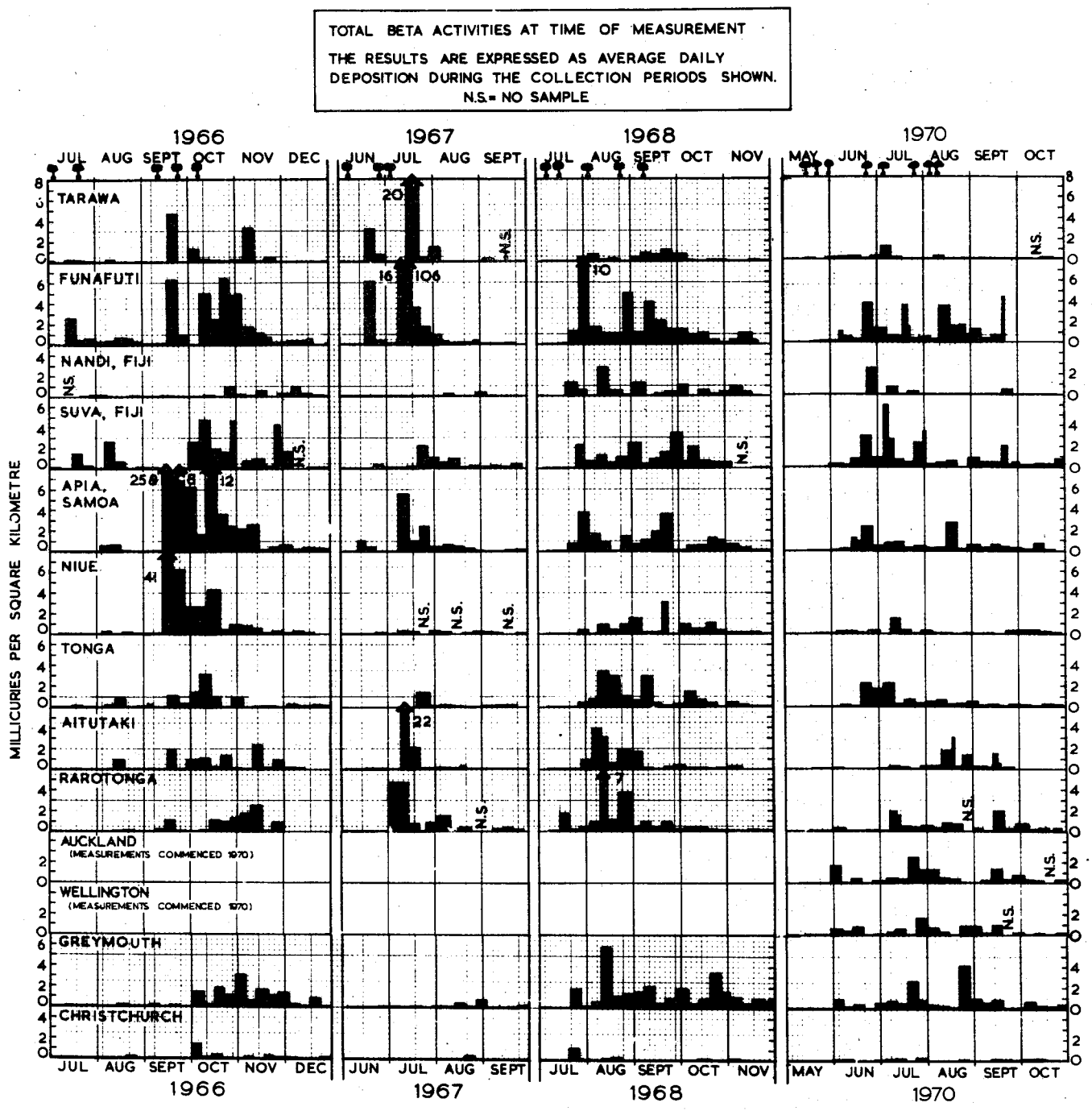


Fig.6 FISSION PRODUCTS IN RAIN - COMPARISON FOUR MONITORING PROGRAMMES

TABLE 5 CONCENTRATION OF FISSION PRODUCTS IN RAIN AT STATIONS WITH HIGHEST LEVELS 1966-1968, 1970

Year	Station	Month of Highest Level	Average Concentration pCi/litre	Entire Monitoring Period	Average Concentration pCi/litre	Per Cent of Reference Level For Continuous Drinking
1966	Apia, Samoa	30 Aug.-27 Sept.	11,800	July-Dec.	1,530	25%
1967	Funafuti	1 July-29 July	1,53(	June-Sept.	530	9%
1968	Funafuti	3 Aug.- 2 Sept.	507	July-Nov.	211	4%
1970	Suva, Fiji	4 July- 1 Aug.	158	May -Oct.	139	2%

It must be emphasised that the hazard assessment given here is presented for comparison purposes only and is not exact. This assessment is based on the levels of radioactivity actually measured in the samples and these measured levels have not been adjusted for radioactive decay which has occurred since collection.

Unavoidable delays occur in measuring samples from those Pacific Island stations which have no air service and have infrequent shipping schedules. For this reason, the number of days between mid-collection and measurement has been given with each individual result tabled in the preceding quarterly reports, and is also given on the top of each column in Fig.5. An adjustment of a measured level to the level at the time of collection can often be made after repeated measurements on a sample, but this is only practicable if the sample transport delay is not too long and the measured radioactivity is sufficiently high. A few suitable samples have been so assessed to establish the date of origin of the fission products and the activity at collection. The dating of fission products in samples, however, during test series involving more than one nuclear explosion is frequently complicated by samples containing a mixture of fission products of different ages.

In order to establish an upper limit to the levels at collection, however, the most pessimistic assumption has been made for each rainwater sample collected during the 1970 monitoring programme i.e. the fission products in the sample derived from the most recent nuclear explosion prior to collection. On this basis the level of fission products at collection has been calculated for each sample and an upper limit for the average concentration during the entire monitoring period has been established for each station. Such calculations show that at no station has the average level during the monitoring period approached the reference level.

The pattern of the increases in radioactive fallout during 1970 is very similar to that observed during 1968. The levels, however, have been somewhat lower during 1970.

3. Strontium-90 in Rain

(1) Routine Measurements at Nine New Zealand and Two Pacific Island Stations.

The monthly values of strontium-90 deposition and rainfall are shown in Fig.7 for each station. In Fig.2 the New Zealand country-wide average levels of deposition and concentration are shown. Highest levels were reached in New Zealand during late 1964 and early 1965. These levels were caused by delayed stratospheric fallout originating from the U.S.S.R. and U.S.A. nuclear tests in 1961 and 1962. Levels then fell steadily until they reached a minimum in 1968. The rate of decline was halted, however, by the French tests in the South Pacific during recent years and levels increased to 50% above the minimum during 1969 and 25% above the minimum during 1970. The levels over the last two years, however, are still only about one third of the peak level in 1964. Table 6 lists the annual deposition at individual stations and the country-wide average deposition since 1960.

TABLE 6 ANNUAL DEPOSITION OF STRONTIUM-90 mCi/km^2

New Zealand Stations	Annual Rainfall* (cm)	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Kaitaia	139				1.8	4.1	3.1	1.6	1.0	0.9	1.5	1.0
Auckland	127	1.2	1.1	1.8	2.0	4.0	2.9	1.3	0.9	0.7	1.3	0.9
New Plymouth	151				2.0	5.3	4.2	1.9	1.3	1.0	1.5	1.2
Havelock Nth	71	0.7	0.8	1.0	1.0	1.6	1.7	0.8	0.5	0.6	0.7	0.6
Wellington	132	0.8	1.1	1.8	2.0	3.4	3.9	1.6	1.0	0.9	1.1	1.2
Greymouth	248	1.5	2.2	2.8	3.7	7.8	5.9	2.2	1.7	1.4	2.2	2.1
Christchurch	57	0.5	0.7	0.7	1.2	1.3	1.7	0.7	0.4	0.4	0.7	0.5
Dunedin	59				1.0	1.8	2.0	0.7	0.6	0.4	0.7	0.5
Invercargill	105	0.5	1.2	1.2	1.7	3.0	2.8	1.1	0.9	0.5	1.2	0.7
Country-Wide Average		0.9	1.2	1.6	1.8	3.6	3.1	1.3	0.9	0.8	1.2	1.0
Suva, Fiji	276		1.0	1.6	2.4	2.5	2.0	1.2	0.8	1.0	1.3	0.9
Rarotonga	227**								(0.9)***	0.7	0.7	1.0

* Mean Annual Rainfall 1963 - 1970 inclusive.

** Mean Annual Rainfall 1967 - 1970 inclusive.

*** Estimate - No Sample Received for 2 Months of 1967.

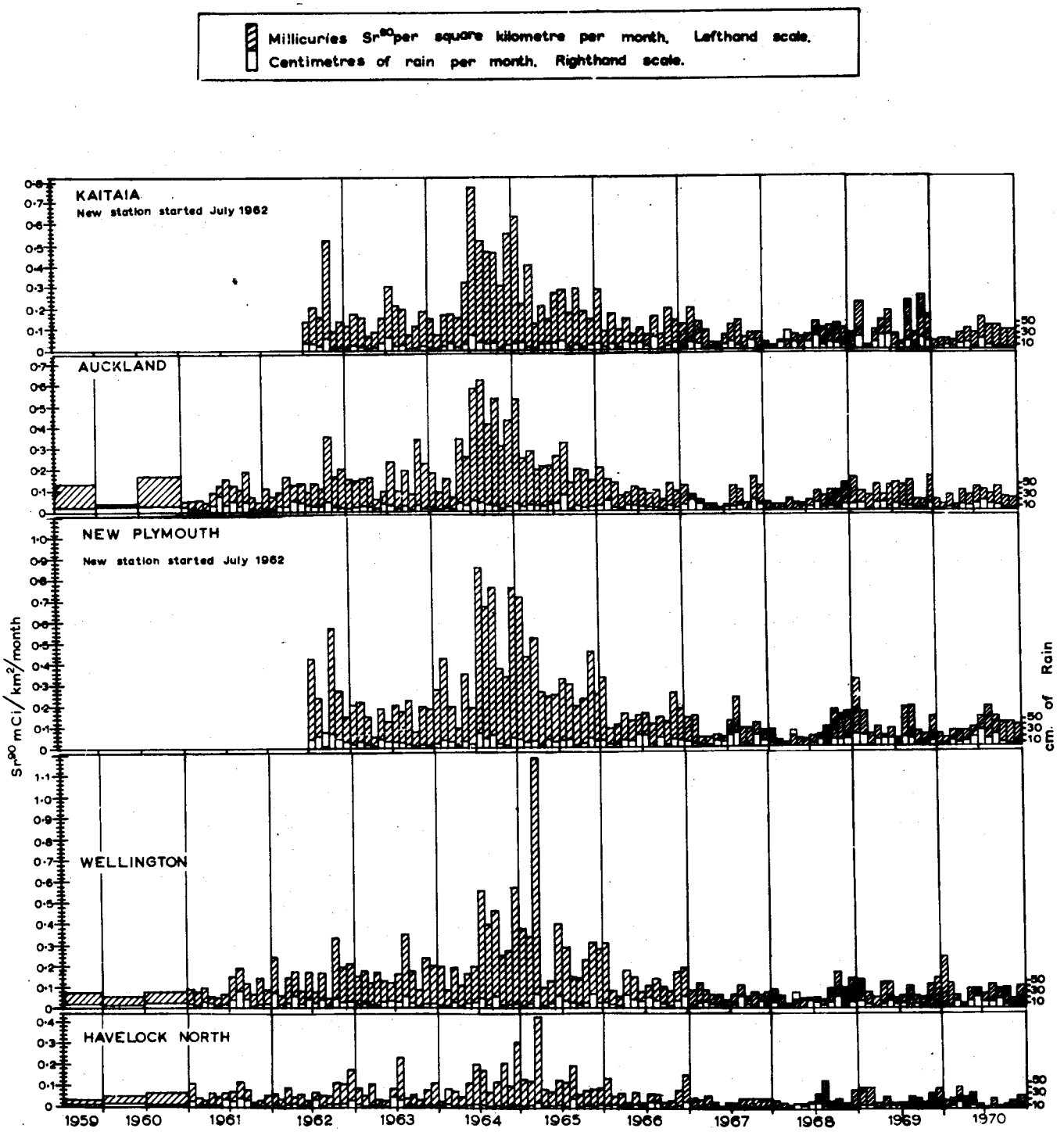


Fig.7 STRONTIUM-90 IN RAIN - INDIVIDUAL STATIONS

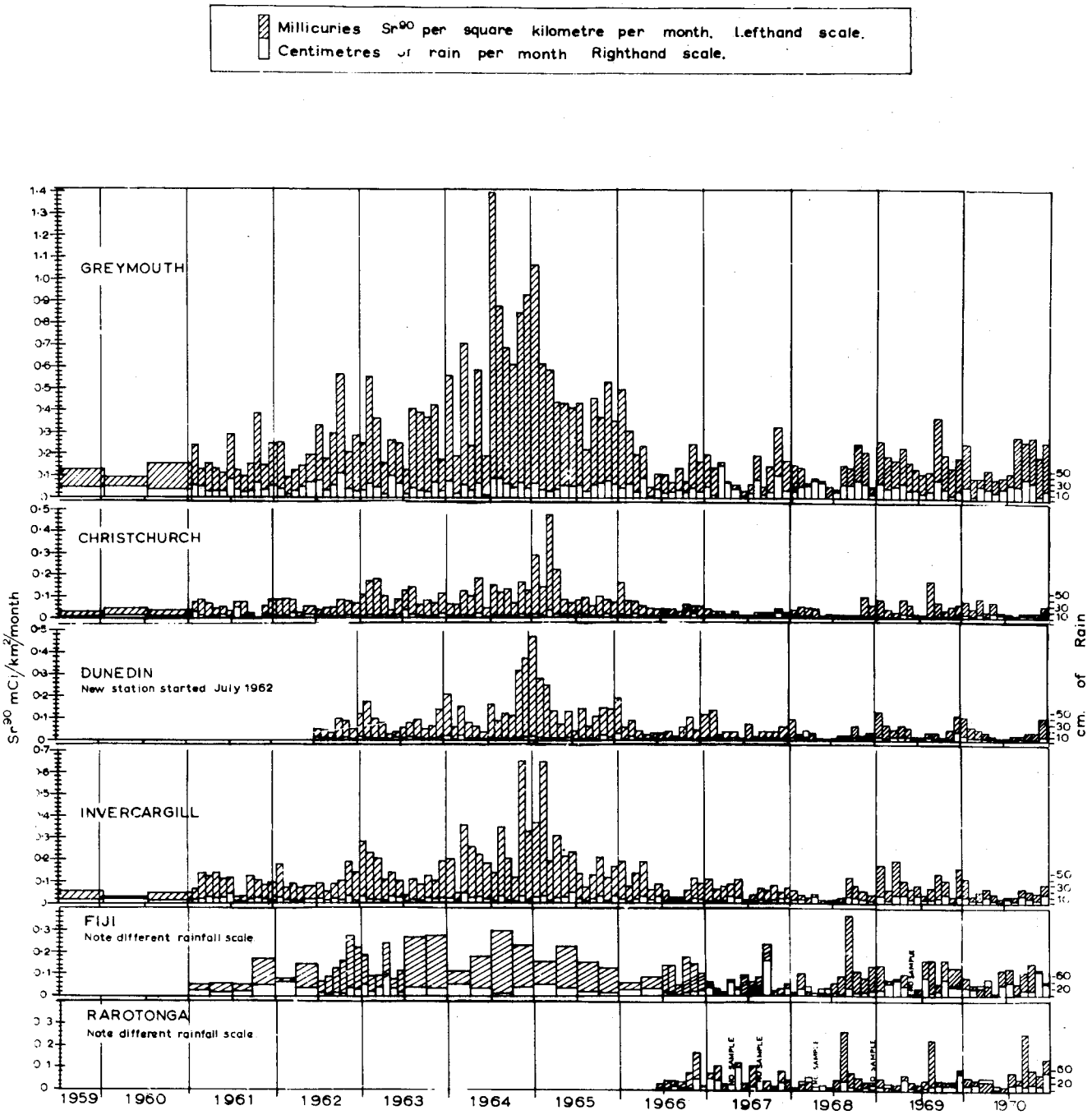


Fig.7 (Continued) STRONTIUM-90 IN RAIN - INDIVIDUAL STATIONS

(2) Comparison with Two Northern Hemisphere Stations. Annual depositions of strontium-90 since 1954 at New York City and at Milford Haven in the United Kingdom are listed in Table 7. The New Zealand country-wide average depositions since 1960 are also listed for comparison. (The values for New York City are taken from the Quarterly Summary Report HASL-242 APP. of the Health and Safety Laboratory, United States Atomic Energy Commission. The Milford Haven values have been taken from the United Kingdom Atomic Energy Authority's Report "Radioactive Fallout in Air and Rain: Results to the Middle of 1970", AERE-R6556.)

After the nuclear tests conducted in the northern hemisphere during 1961 and 1962, strontium-90 fallout reached a maximum in 1963 in the northern hemisphere and in 1964 in the southern hemisphere. Since then levels have fallen until about 1967-1970 during which time they have remained fairly steady. Table 7 shows that strontium-90 fallout has been about the same at Milford Haven, New York City and New Zealand during 1969 and 1970. This amounts, in New Zealand, to one third the peak deposition in 1964, while in New York City and Milford Haven the 1963 peaks were about 20 times higher than their present levels.

TABLE 7 ANNUAL DEPOSITION OF STRONTIUM-90 mCi/km^2

Year	Milford Haven	New York City	New Zealand Average
1954	2.0 (Up to end of 1954)	2.8 (Feb.-Dec. incl.)	
1955	2.4	3.6	
1956	2.5	4.4	
1957	2.6	4.4	
1958	5.4	6.2	
1959	5.7	8.7	
1960	1.8	1.6	0.9
1961	2.5	2.4	1.2
1962	9.3	12.3	1.6
1963	20.9	23.8	1.8
1964	11.7	15.9	3.6
1965	4.8	5.5	3.1
1966	3.1	2.4	1.3
1967	1.2	1.6	0.9
1968	1.2	1.3	0.8
1969	0.9	1.4	1.2
1970	0.6 (To end of June)	1.5	1.0

4. Strontium-90 Cumulative Deposition

The annual depositions in Table 7 have been totalled and corrected for radioactive decay and are presented graphically in Fig.8 as cumulative deposition. (The dotted portion of the curve for New Zealand is based on soil

measurements undertaken by the U.S. Department of Agriculture on samples from three collecting sites. The part of the curve from July 1959, to July 1962 is derived from our measurements on rain samples from six collecting stations. From July 1962 the average result from our network of nine rainwater collecting stations has been used.)

Due to the steadily decreasing levels of fallout since 1963, the situation was eventually reached in the northern hemisphere during 1967 that the reduction of accumulated strontium-90 by radioactive decay was greater than the annual deposit. Since 1967, therefore, there has been a slight but distinct downward trend in the curve for cumulative deposition.

In New Zealand, however, where the total accumulation is much less, reduction by radioactive decay has been less significant. Interhemispheric transfer of strontium-90 and the injection of fresh fission material into the southern hemisphere during the French nuclear tests have resulted in a continuing slight increase in the total accumulation of strontium-90.

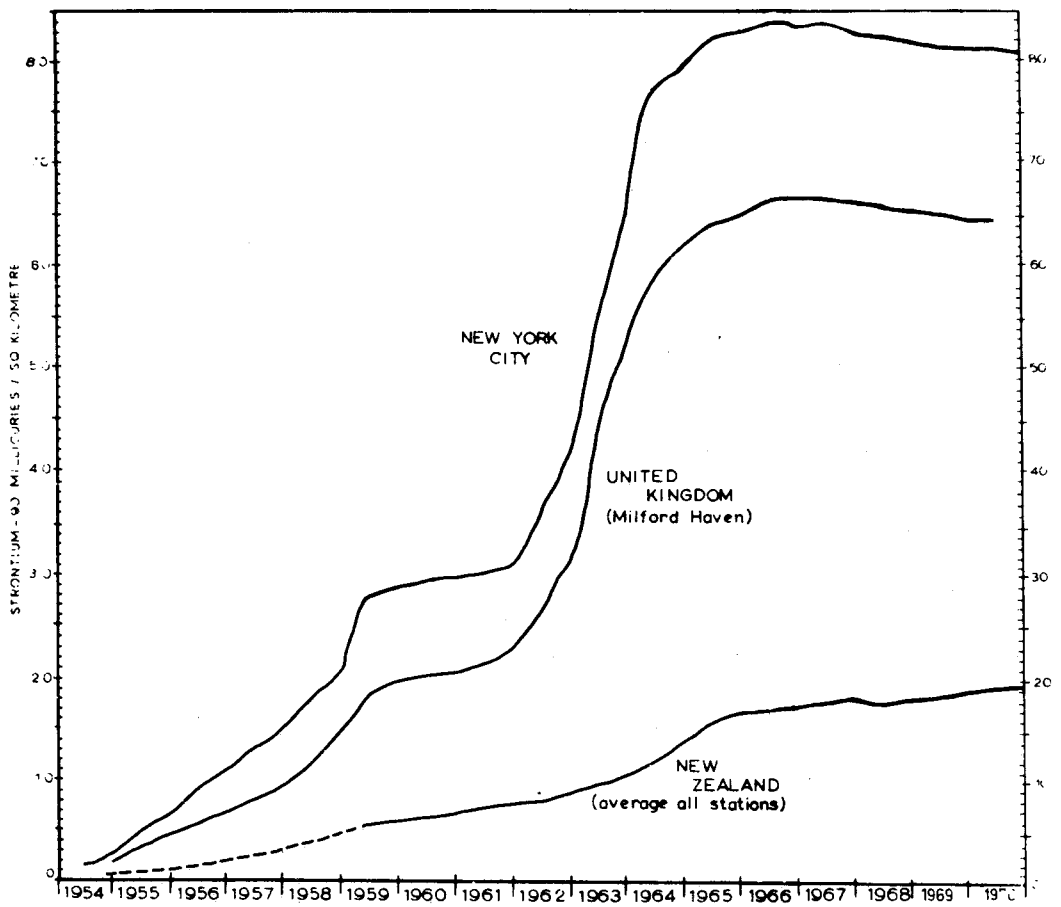


Fig.8 CUMULATIVE DEPOSITION OF STRONTIUM-90 - COMPARISON

5. Strontium-89/Strontium-90 Ratios in Rain

Since July 1966 all monthly rainwater collections routinely measured for strontium-90 have also been measured for the relatively short lived strontium-89 (half-life 50 days). During periods of nuclear testing in the atmosphere strontium-89 is readily detectable and the evaluation of the ratio strontium-89/strontium-90 often allows an estimate of the contribution made by current tests to the total strontium-90 deposit.

In Fig.9 values of the ratio and also the strontium-90 deposit are plotted each month for Suva, Rarotonga, and New Zealand (country-wide average). The values are plotted on a logarithmic scale which is more suitable for showing radioactive decay. Measurements of strontium-89 were discontinued during January to June 1968, and January to April 1970 when levels had dropped to below detectable limits.

An analysis of the data shown in Fig.9 allows the following observations to be made for the New Zealand stations:

1966 About 20% of the total strontium-90 deposit during October to December originated from the French tests. The proportion then decreased to about 10% in February 1967.

1967 A similar pattern was evident. About 20% of the total strontium-90 fallout in August was due to the 1967 tests, the proportion decreasing to about 10% in November.

1968 and 1969 Nearly half the strontium-90 fallout during the second half of 1968 came from the 1968 tests and this proportion was probably maintained or even increased during 1969.

1970 About one quarter to one third of the strontium-90 deposit during the second half of 1970 derived from the 1970 tests.

At the Pacific Island stations, which are at about the same latitude as the test site in the Tuamotu Archipelago, the proportion of the total strontium-90 deposit contributed by each test series was higher than that in New Zealand as shown in Fig.9. The total deposition of strontium-90, however, was not significantly different from the New Zealand average. These facts are consistent with the lower level of stratospheric fallout at equatorial regions compared to mid-latitudes. It is reasonable to conclude that had the French tests not taken place in the South Pacific, strontium-90 fallout in the Southern Hemisphere, originating from nuclear tests prior to 1962, would have reached very low values over recent years in New Zealand and even lower values in the Pacific Islands.

A further inspection of Fig.9 shows that the ratio decreased with a half-time of less than 50 days (the half-life of strontium-89) after the 1966 and 1967 tests. This is probably due to wash-out of tropospheric debris produced by the low yield nuclear devices tested, combined with further deposition of strontium-90 from the stratospheric resevoir which has resulted from past (mainly northern hemispheric) testing.

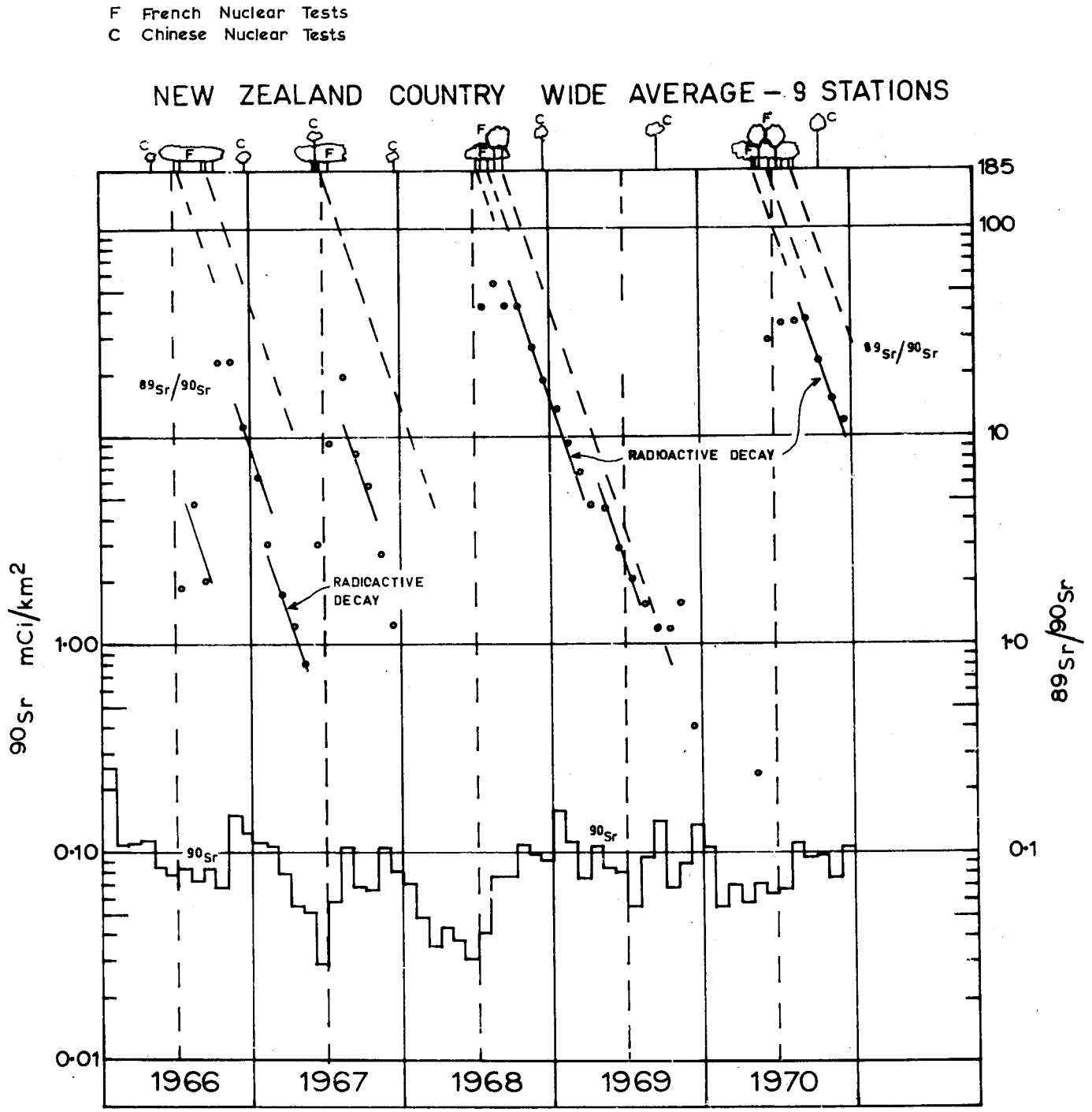


Fig.9 STRONTIUM-89/STRONTIUM-90 RATIO IN RAINWATER AND STRONTIUM-90 DEPOSITION

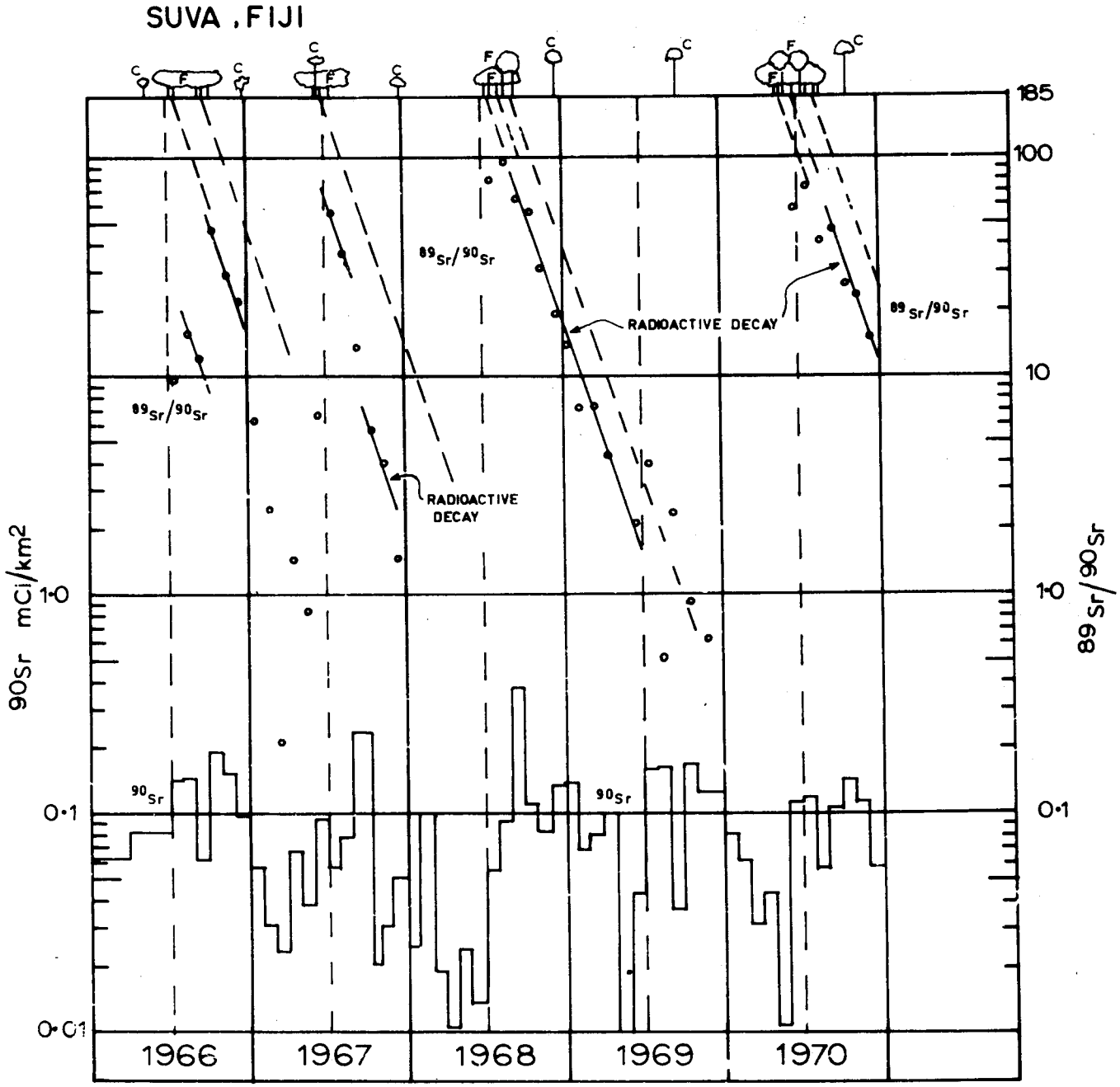


Fig.9 (Continued) STRONTIUM-89/STRONTIUM-90 RATIO IN RAINWATER AND STRONTIUM-90 DEPOSITION

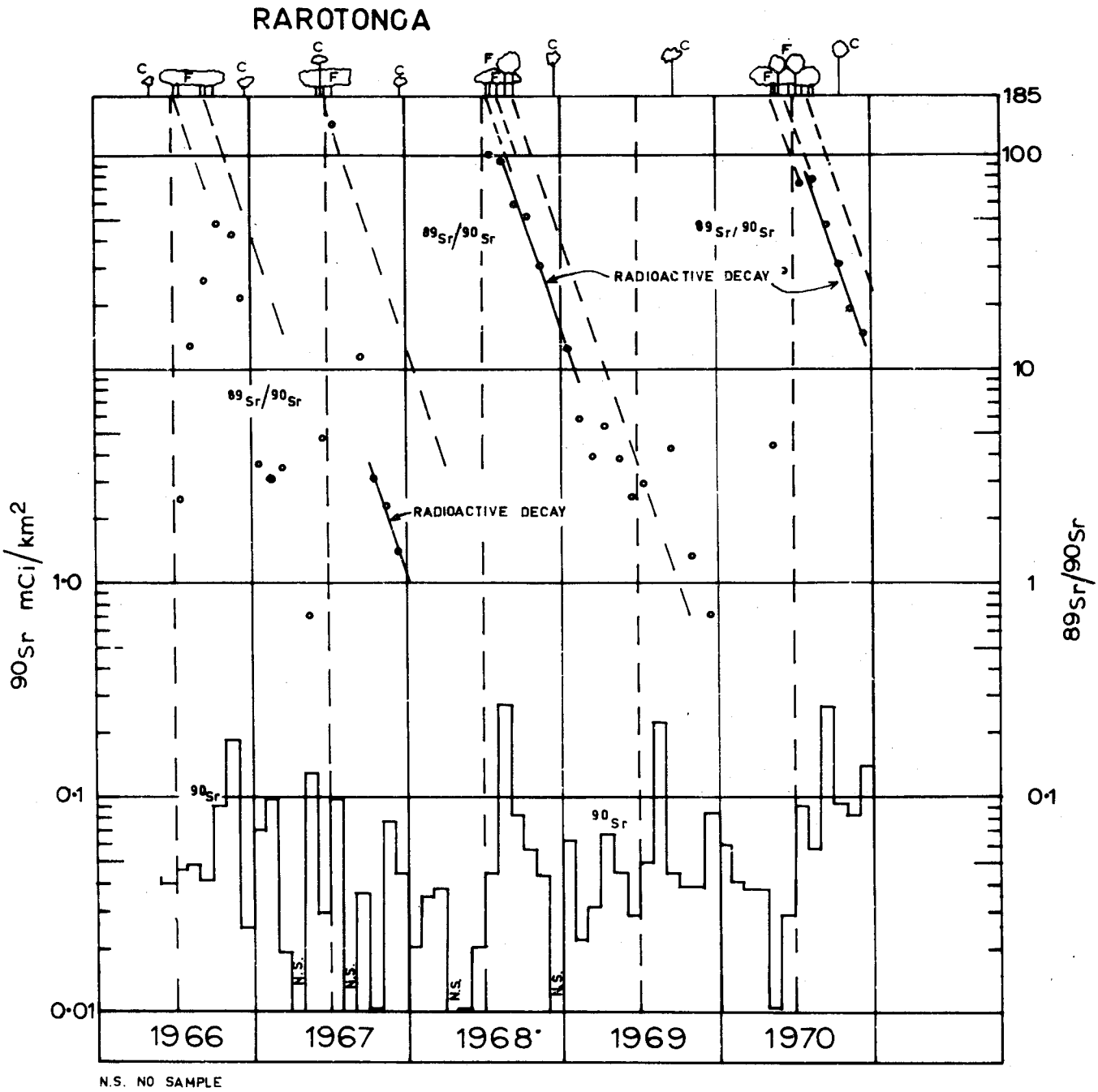


Fig.9 (Continued) STRONTIUM-89/STRONTIUM-90 RATIO IN RAINWATER AND STRONTIUM-90 DEPOSITION

After the 1968 tests, however, which included stratospheric injection of fission products for the first time by the two hydrogen bombs tested, the ratio decreased with a half-time very close to 50 days. A similar pattern is evident after the 1970 tests which also included the detonation of two high power devices. It is noted that some of the values of the ratio towards the end of 1969 are greater than the maximum values expected from the 1968 tests and this may be due to interhemispheric transfer of debris from the Chinese high yield nuclear explosion of 27 December 1968. (See discussion NRL-F/38 pp 18,19.)

6. Strontium-90 in Milk

(1) Routine Measurements at Nine New Zealand Stations. The levels of strontium-90 in milk at individual stations are shown in Fig.10 and the country-wide averages since about 1960 are shown in Fig.2. The average levels in New Zealand milk reached their maximum values of about 11 Strontium Units during 1964 and 1965 when the deposition of strontium-90 in rain was also a maximum. Levels then fell steadily until they reached a minimum of about 5 Strontium Units in 1968. This decrease, however, has been at a slower rate than the decrease in strontium-90 in rain because of the accumulating deposit of strontium-90 in soil and the continuing uptake from soil into grass. The rate of decline was halted in 1968 by the French tests in recent years and levels in milk then increased to about 6.6 Strontium Units in 1969 and 1970.

During 1970 individual station levels ranged from an average of 2.2 Strontium Units at Christchurch to 21.0 Strontium Units at Westland. Table 8 lists the average levels at individual stations and the country-wide average levels for each year since 1962.

TABLE 8 AVERAGE LEVELS OF STRONTIUM-90 IN MILK - STRONTIUM UNITS

	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	Average 1962-1970
Northland	4.5	6.3	7.5	11.2	10.6	6.5	5.1	4.1	6.3	5.2	7.0
Auckland		5.5	5.3	9.1	9.4	6.1	5.2	3.8	6.0	5.1	6.2
Waikato	4.1	4.9	5.6	9.5	9.8	6.3	5.0	4.1	5.4	5.2	6.2
Taranaki	7.1	9.4	9.9	17.1	16.7	12.5	10.4	8.0	9.4	9.7	11.5
Palmerston Nth		4.3	4.9	7.1	8.4	4.8	3.9	3.6	5.8	3.6	5.2
Wellington					8.8	6.1	5.4	4.8	5.1	4.7	
Westland	12.7	13.5	17.2	26.0	28.8	22.7	17.8	14.0	17.9	21.0	19.9
Christchurch	1.6	2.1	2.7	2.6	4.3	2.4	1.9	1.6	1.7	2.2	2.4
Dunedin		3.0	3.7	4.1	7.4	4.0	3.1	2.4	3.0	2.5	3.7
Country-Wide Average		6.1	7.1	10.8	11.6	7.9	6.4	5.2	6.7	6.6	7.8

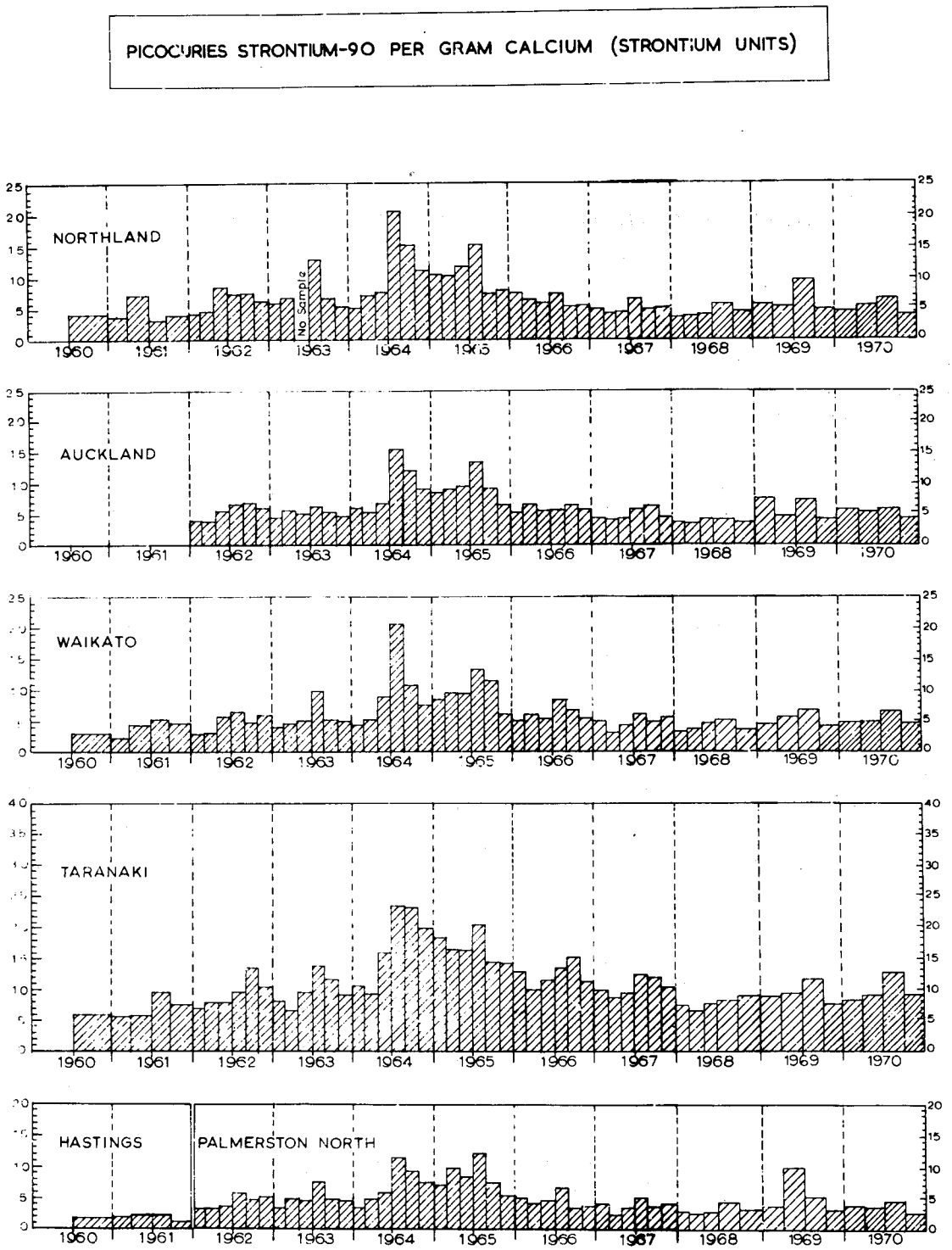


Fig.10 STRONTIUM-90 IN MILK - INDIVIDUAL STATIONS

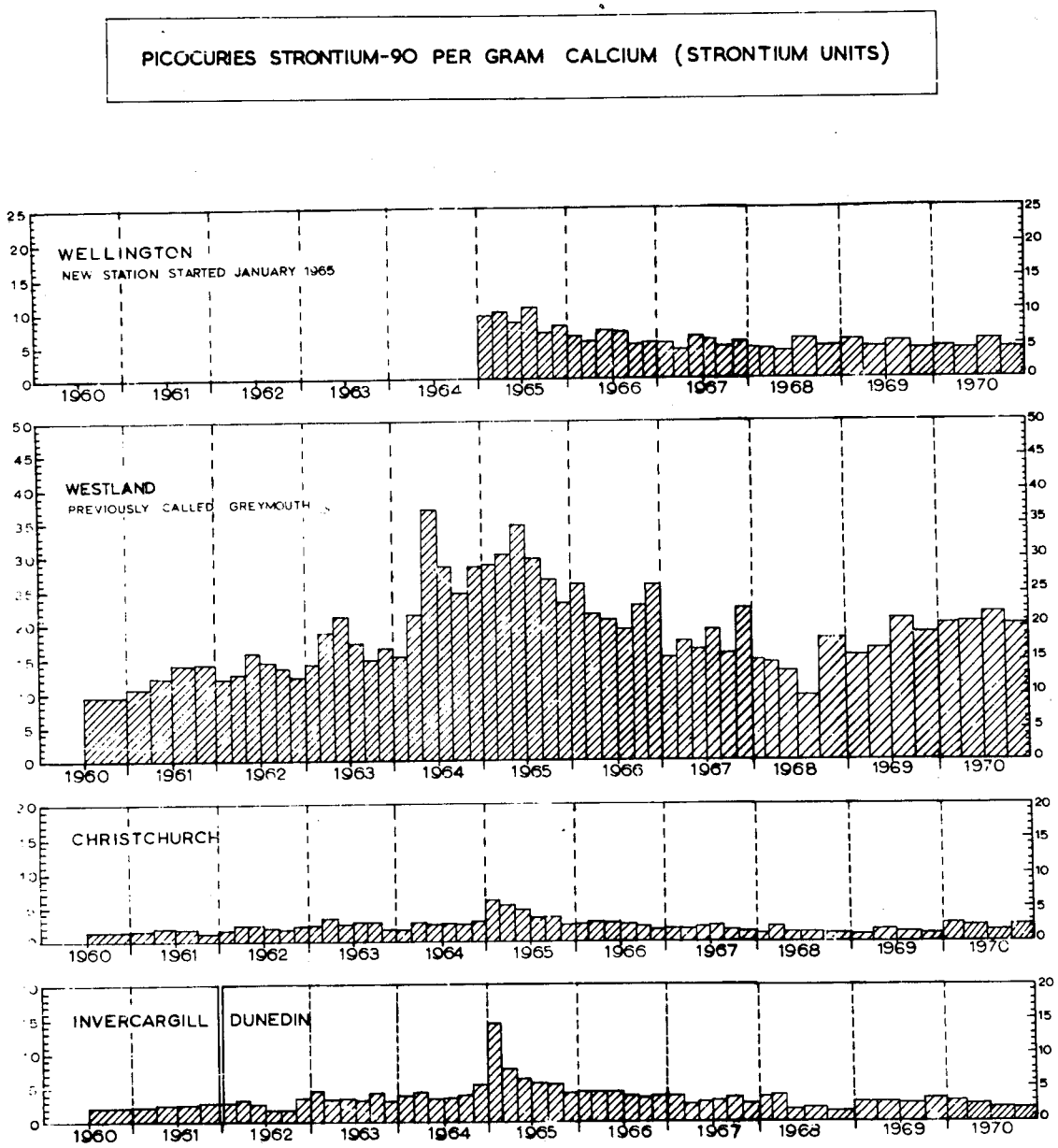


Fig.10 (Continued) STRONTIUM-90 IN MILK - INDIVIDUAL STATIONS

(2) Comparison with Two Northern Hemisphere Stations. The country-wide average levels of strontium-90 in New Zealand milk are compared with levels in Canadian and New York City milk in Fig.11. The average level for each two-monthly period has been plotted for each locality up to June 1968. Thereafter the average level for each three-monthly level has been plotted. (The Canadian values are taken from the reports "Data from Radiation Protection Programs" of the Radiation Protection Division, Department of National Health and Welfare, Canada, and are the averages of the results for all collecting stations. The New York City values are the average of results from samples collected daily from the local milk supply, and are taken from the Fallout Program, Quarterly Summary Reports of the Health and Safety Laboratory, United States Atomic Energy Commission.)

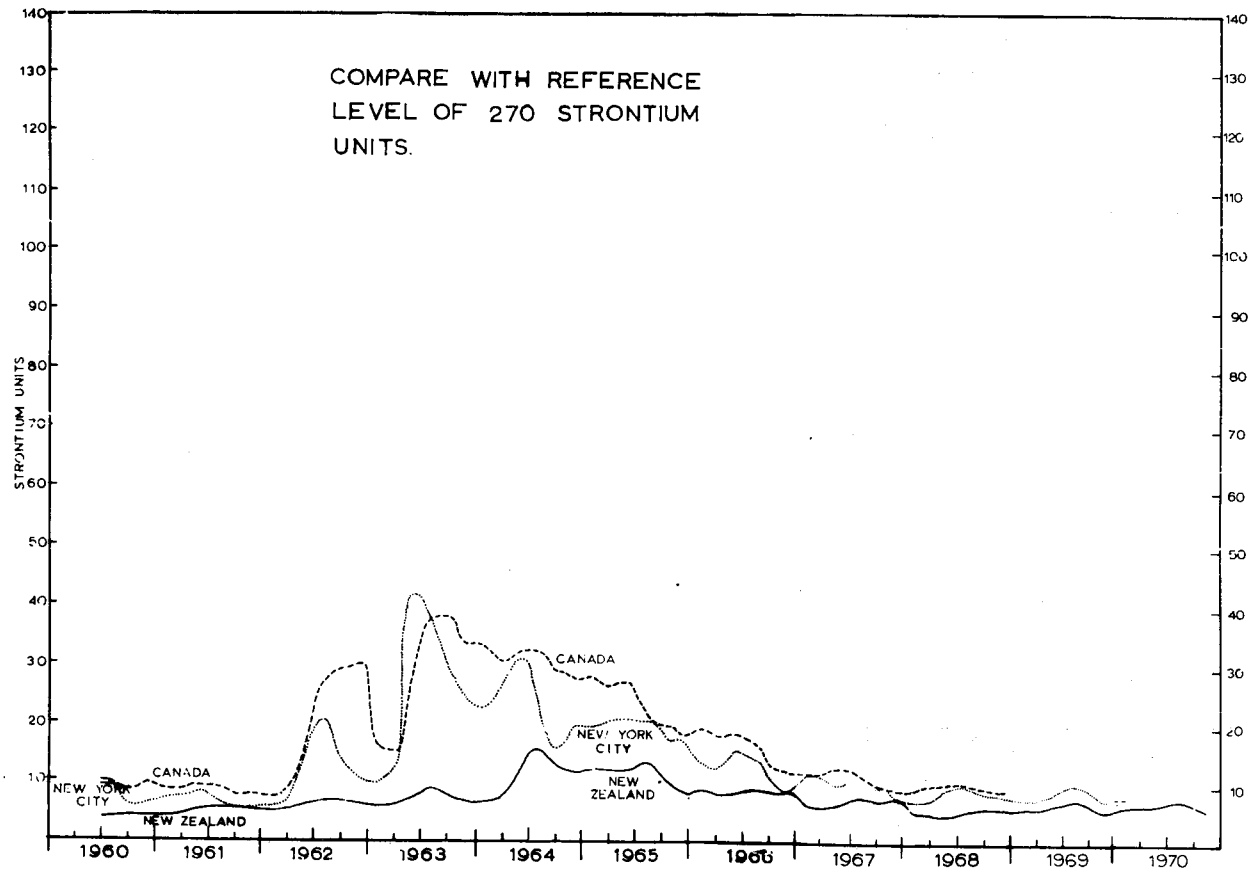


Fig.11 STRONTIUM-90 LEVELS IN MILK - COMPARISON

The strontium-90 levels in milk reached their maximum values in 1963 and 1964 at the northern hemisphere stations after the northern hemisphere nuclear tests of 1961 and 1962, whereas, the level in New Zealand milk reached its maximum about one year later i.e. in 1964 and 1965. This delay was caused by interhemispheric transfer of strontium-90 injected into the northern hemisphere stratosphere during the 1961, 1962 tests. The maximum levels at the two northern hemisphere stations were 2 to 3 times as high as the maximum in New Zealand. Subsequently levels declined and in recent years levels at the northern hemisphere stations have been only slightly higher than the average New Zealand level.

(3) Hazard Assessment. For health hazard assessment it is more significant to consider average levels over many years. If we postulate that the average level in New Zealand milk during the period 1962-1970 is maintained indefinitely in the diet as a whole, and if we accept the observed ratio of strontium-90 in bone to strontium-90 in diet as 1 to 4 then under these steady state conditions levels in the bones of New Zealanders would not exceed the levels listed in Table 9.

TABLE 9 STRONTIUM-90 HAZARD ASSESSMENT (1962-1970)

Station	Strontium Units		% of Reference Level
	Milk	Bone	
Lowest Level (Christchurch)	2.4	0.6	0.9%
Highest Level (Westland)	19.9	5.0	7.5%
Country-Wide Average	7.8	2.0	3.0%

Results of strontium-90 measurements in human bone samples are given in Table 13.

7. Caesium-137 in Milk

(1) Routine Measurements at Nine New Zealand Stations. The levels of caesium-137 in New Zealand milk are shown for each collecting station in Fig.12 and the country-wide average levels are shown in Fig.2. Levels in New Zealand milk reached their maximum values during the first quarter 1965 and then decreased to a minimum in 1968. During the last two years levels have increased slightly as a result of the nuclear tests in the South Pacific. During 1970 average values ranged from 4 pCi/g K at Christchurch to 89 pCi/g K at Taranaki with a country-wide average of 25 pCi/g K which is less than half the peak value in 1965. Table 10 lists the average levels at individual stations and the country-wide average levels since measurements commenced.

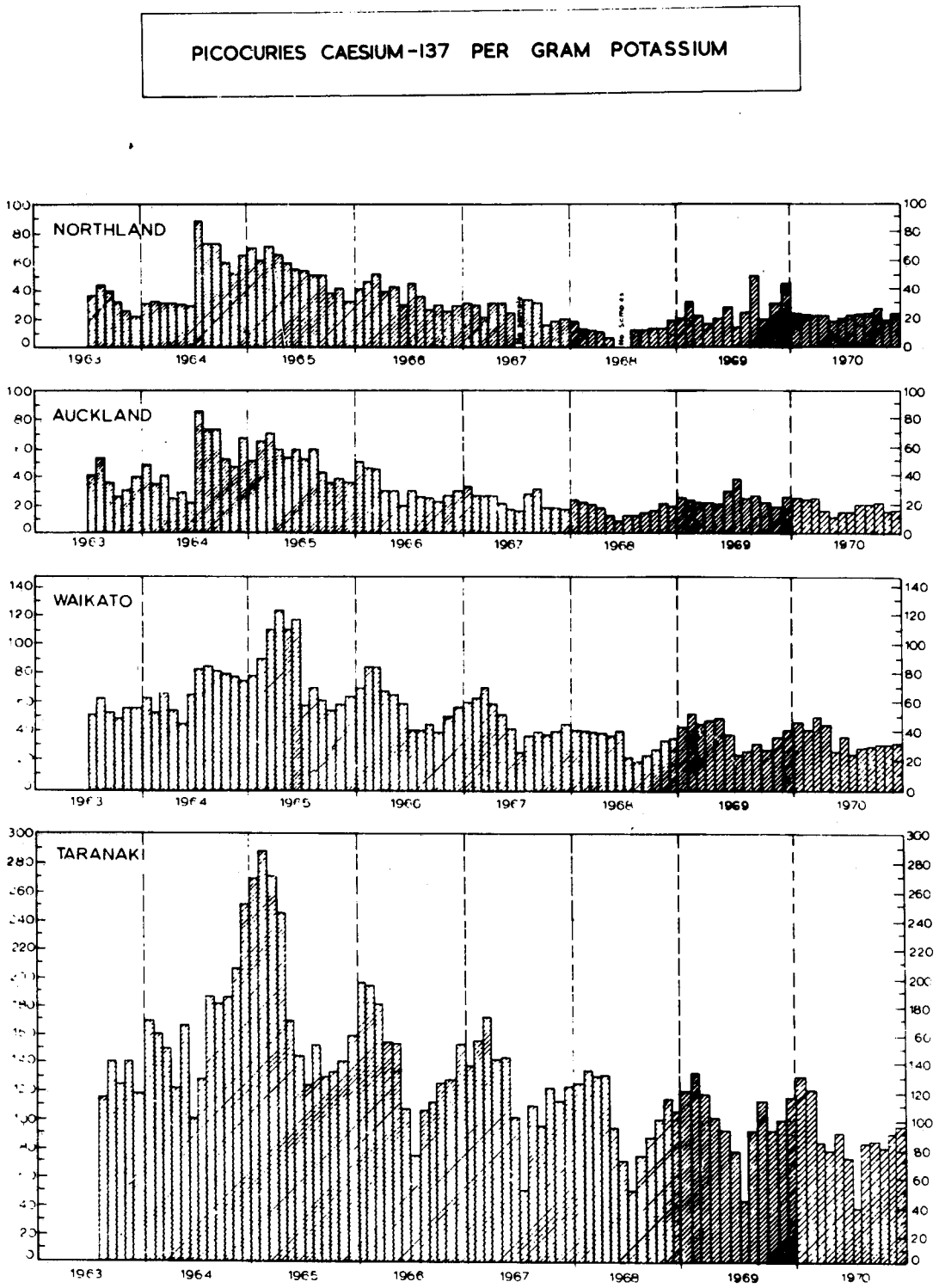


Fig.12 CAESIUM-137 LEVELS IN MILK - INDIVIDUAL STATIONS

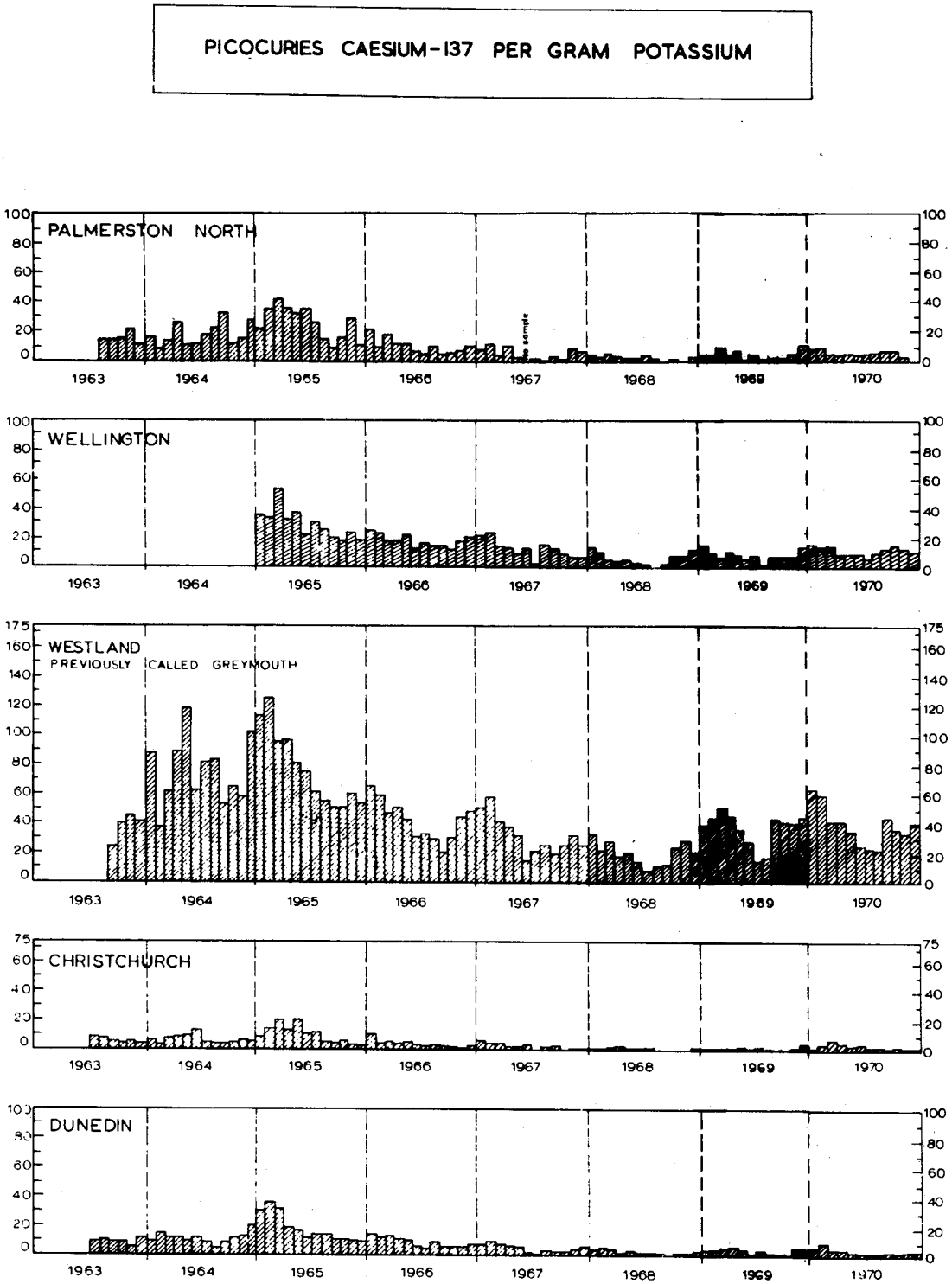


Fig.12 (Continued) CAESIUM-137 LEVELS IN MILK - INDIVIDUAL STATIONS

TABLE 10 AVERAGE LEVELS OF CAESIUM-137 IN MILK - pCi/g K								
	1964	1965	1966	1967	1968	1969	1970	Average 1964 - 1970
Northland	49	54	37	26	15	27	22	33
Auckland	51	53	33	26	18	26	18	32
Waikato	69	84	60	48	36	41	35	53
Taranaki	168	185	141	123	102	101	89	130
Palmerston North	19	26	11	7	3	5	6	11
Wellington	(25)*	29	18	13	7	9	11	16
Westland	76	77	43	33	21	38	39	47
Christchurch	7	11	4	3	1	2	4	5
Dunedin	11	18	9	5	3	4	5	8
Country-Wide Average	53	60	39	31	23	28	25	37

* Estimated for averaging purposes.

(2) Hazard Assessment. For health hazard assessment average levels over longer periods are more significant. During the period 1964-1970 inclusive average station levels ranged from 5 pCi/g K at Christchurch (less than 0.1% of the reference level) to 130 pCi/g K at Taranaki (about 2% of the reference level). The country-wide average level over the same period was 37 pCi/g K which is about 0.5% of the reference level.

8. Iodine-131 in Milk and Cattle Thyroid

(1) General. Even though iodine-131 has a short half-life of 8 days, its high yield in nuclear explosions, and its property of concentrating in thyroid make it the radionuclide of most health concern amongst the shorter-lived fission debris. Iodine-131 is present in milk within one day of pasture contamination. After each cessation of nuclear tests in the atmosphere, iodine-131 in the environment is reduced by radioactive decay to negligible proportions within a month or two.

The reference level in milk is based on the most critical age group (young children) and is 200 pCi/litre as an average intake over one year, or higher concentrations for correspondingly shorter times. During the 1966-1968 and 1970 monitoring programmes, milk from seven New Zealand stations and two Pacific Islands has been measured for radioiodine. In addition, because of the enhanced sensitivity of detection of iodine-131 in animal thyroids, these samples have been used as an indicator of the arrival of iodine-131 in New Zealand.

(2) Levels in Milk During the 1970 Extended Monitoring Programme - 9 Stations. Thrice weekly collections of milk from 7 New Zealand stations, Suva (Fiji), and Apia (Samoa) were started on 18 May. Levels remained below the minimum detectable level (2 pCi/litre) until 3 to 5 June when they increased

at all stations. This monitoring service concluded on 9 October when levels were again at about the minimum detectable level at all stations. The results for individual collections were given in the quarterly reports NRL-F/39 and NRL-F/40. Table 11 lists the highest level measured and also the average level for each station during the monitoring programme.

TABLE 11 IODINE-131 IN MILK (pCi/litre) - 1970 MONITORING PROGRAMME

Collecting Stations	Highest Level	Average Level
New Zealand		
Auckland	54	7
New Plymouth	27	6
Wellington	25	6
Greymouth	39	9
Christchurch	13	2
Dunedin	7	2
Invercargill	34	4
Average		5
Pacific Islands		
Suva, Fiji	104	25
Apia, Samoa	370	43

(3) Comparison with Milk Levels During Previous Monitoring Programmes and Hazard Assessment. In Fig.13 levels of iodine-131 in each milk collection at the two Pacific Island stations and also the maximum, minimum, and average levels on each sampling day at the New Zealand stations are shown for each monitoring period since 1966.

In Table 12 the average levels during each monitoring period are listed and from these values the average intake over each year is calculated for hazard assessment.

TABLE 12 IODINE IN MILK - COMPARISON AND HAZARD ASSESSMENT

Stations	pCi/litre								% of Reference Levels			
	During Monitoring Period				Average For Year							
	1966	1967	1968	1970	1966	1967	1968	1970	1966	1967	1968	1970
New Zealand Average	7	<5	5	5	4	1	2	2	2%	<1%	1%	1%
Suva, Fiji	*	23	36	25	(50)*	8	12	10	(25%)*	4%	6%	5%
Apia, Samoa	*	68	28	43	(40)*	23	9	17	(20%)*	11%	5%	9%

* Pacific Island collections during 1966 did not cover the entire monitoring period. The bracketed values are estimates only (See NRL-F/33 p.35 for discussion).

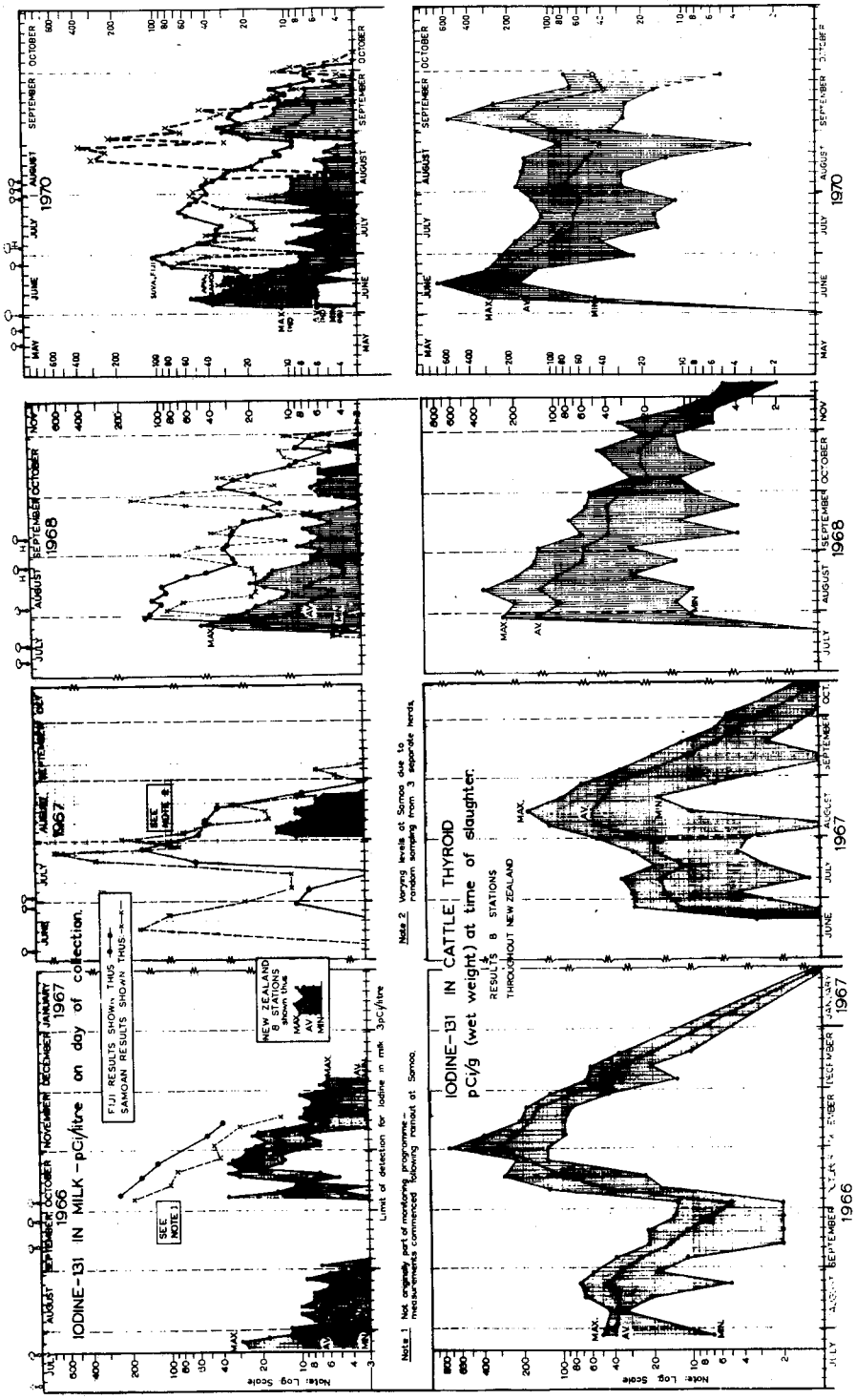


Fig.13 IODINE-131 IN MILK AND CATTLE THYROID

(4) Levels in Cattle Thyroid. Samples of cattle thyroid from the eight collecting stations listed in Section A were obtained weekly commencing 25 May 1970 and finishing 5 October 1970. Levels were below the minimum detectable level (0.1 pCi/g wet weight) until 8 June when increases were recorded at all stations. The results for individual samples were given in the quarterly reports NRL-F/39 and NRL-F/40. The maximum levels reached at any station during each of the four monitoring periods were:

1966	31 October	726 pCi/g at	Gore
1967	14 August	169 " "	Westport
1968	12 August	356 " "	Palmerston North
1970	15 June	696 " "	Hastings

In Fig.13 the maximum, minimum, and average levels on each sampling day are shown for each monitoring period on the same time scale as the milk levels. While there is some obvious correlation between the two (i.e. the average concentration in milk expressed as pCi/litre is approximately equal to one-tenth the average concentration in thyroid expressed as pCi/g) the peak activities do not coincide in time, the rise and fall of the thyroid activity lagging slightly behind that of milk.

9. Lead-210 in Rain

Lead-210 is produced in the atmosphere by decay of radon-222 diffusing from land surfaces. The resulting "natural fallout" of lead-210 is of health interest. During 1965 and 1966 a special survey was conducted at four sites selected from the network of rainwater stations which supply regular monthly samples for strontium-90 determination. The results of this survey were published in our Annual Summary 1967, Report No. NRL-F28. The results showed that lead-210 deposition in 1965 had been about twice that in 1966 and the possibility of lead-210 having been formed artificially in one or more of the explosions during the 1961 and 1962 test series was mentioned.

In May 1967 this survey was re-started at all collecting stations and the results for monthly collections up to December 1970 are shown in Fig.14. During this period the country-wide average deposition of lead-210 has ranged from 0.05-0.26 mCi/km^2/month, with a mean value of 0.12 mCi/km^2/month i.e. about the same as in 1966.

10. Strontium-90, Radium-226 and Lead-210 in Human Bone

Table 13 summarises all the results of measurements of long lived artificial and natural radionuclides which have been made on New Zealand ashed human bone samples.

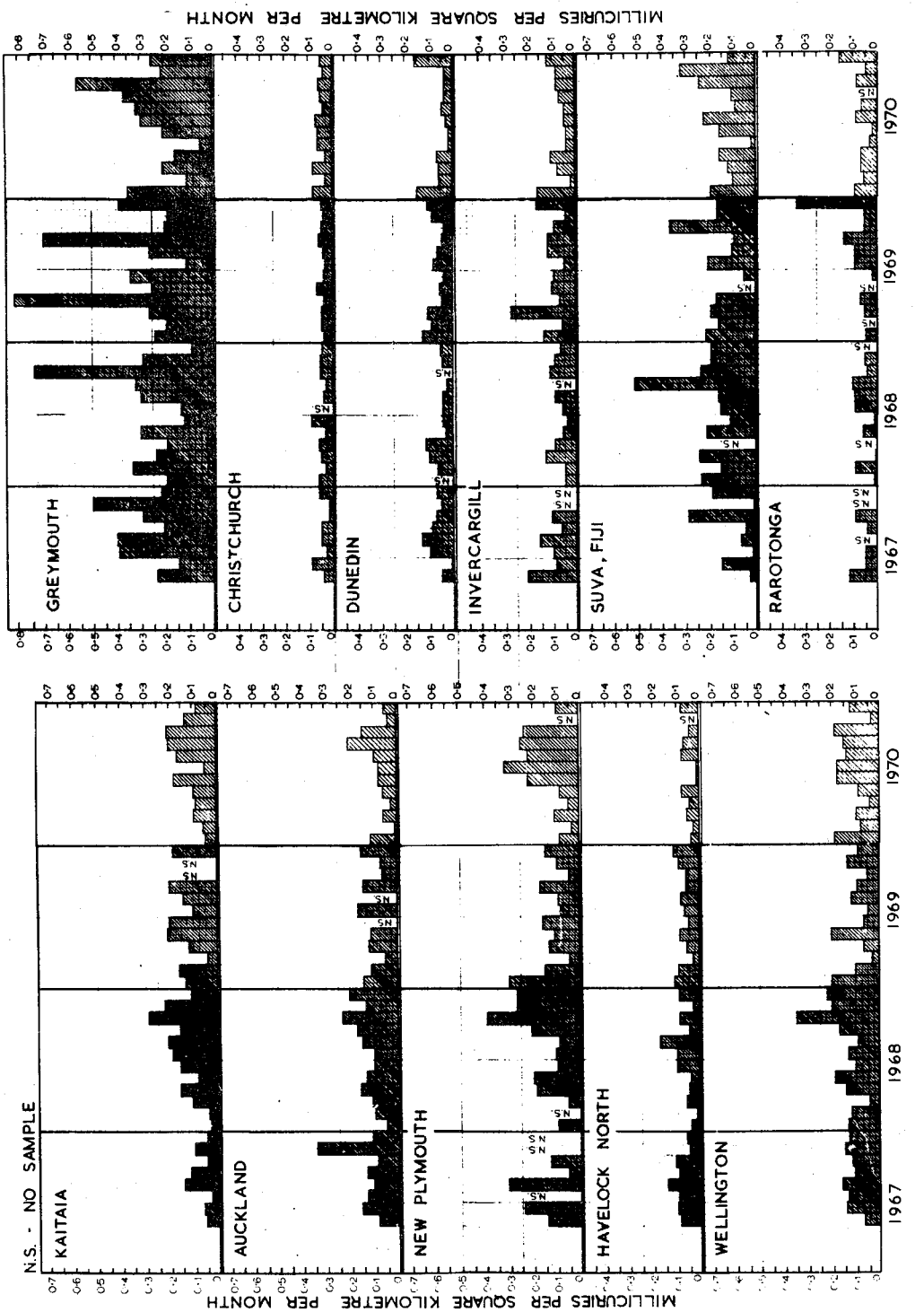


Fig.14 LEAD-210 IN RAIN

The areas from which the samples have been obtained within New Zealand are classified according to mean annual rainfall as follows:

Low rainfall	up to 100 cm per year
Medium rainfall	100 to 150 cm per year
High rainfall	over 150 cm per year

TABLE 13 RADIONUCLIDES IN HUMAN BONE

Sample Data					Radionuclide Levels		
					Artificial	Natural	
Sample No.	Rainfall Area	Date of Death	Age at Death	Bone	Strontium-90 pCi/g Ca	Radium-226 pCi/g ash	Lead-210 pCi/g ash
3	Low	7/61	5m	F,V,R	0.9	0.016	0.047
4	"	7/61	9y	F,V	0.6	0.011	0.053
7*	"	9/61	23y	F,V	0.7	0.214	0.355
1	"	6/61	53y	F	<0.1	0.026	0.101
2	"	7/61	60y	F	<0.1	0.011	0.099
33	"	9/61	78y	H	0.2	0.012	0.054
34	"	9/61	79y	H	0.1	0.013	0.040
29	"	2/61	83y	H	0.1	0.017	0.050
5	High	9/61	68y	F	0.2	0.012	0.080
31	"	11/61	68y	H	0.3	0.010	0.074
8	"	10/61	80y	F	<0.1	0.040	0.106
6	"	9/61	85y	F	<0.1	0.010	0.111
10	Low	5/62	7y	F	0.5	0.020	0.094
36	"	1/62	56y	H	0.3	0.009	0.118
32	Medium	2/62	53y	H	0.3	0.046	0.193
30	"	2/62	67y	H	0.2	-	-
19	High	12/62	9m	F	3.2	0.036	0.079
11	"	11/62	1y	F	2.1	-	-
12	"	11/62	2y 6m	F	1.2	0.020	0.060
23	"	12/62	8y	F	1.6	0.026	0.078
9	"	5/62	16y	F	1.4	0.017	0.150
15	"	11/62	16y	F	0.6	0.013	0.057
14	"	11/62	19y	V,R	0.9	0.013	0.190
13	"	11/62	72y	V	0.9	0.021	0.173
16	Low	11/63	4y	F	2.3)	0.009	0.094
16				V	2.5)		
35	Medium	6/63	84y	H	0.3	0.041	0.077
17	High	8/63	1y 3m	F	2.1	0.026	0.096
27	"	12/63	3y 9m	L	2.2	0.012	0.085
18	"	8/63	5y	F	1.3	0.010	0.076
22	"	7/63	5y 6m	F	1.4	0.008	0.050
21	"	1/63	7y	F	0.9	0.026	0.151
20	"	2/63	19y	F	1.4	0.023	0.072

TABLE 13 (continued)

Sample No.	Rainfall Area	Date of Death	Age at Death	Bone	Strontium-90 pCi/g Ca	Radium-226 pCi/g ash	Lead-210 pCi/g ash
25	Low	4/64	SB	L	1.0	-	-
25				R	1.0	-	-
25				V	0.9	-	-
26	"	4/64	SB	L	0.6	-	-
26				R	0.9	-	-
26				V	0.8	-	-
26				S	0.7	-	-
24	"	4/64	6y	F	1.2)	0.021	0.069
24				V	1.0)		
28	High	2/64	6y	L	1.4	0.008	0.058
74	Low	11/66	3y	F	3.0	0.014	
46	"	7/66	7y	F	1.9	0.009	0.036
42	"	6/66	16y 6m	F	1.0	0.074	0.098
43	"	6/66	19y	F	0.5	0.010	0.057
49	**	9/66	18y	F	0.5	0.023	0.085
58	Low	7/66	20y	F	0.9	0.017	0.090
71	"	11/66	21y	F	0.5	0.037	
68	"	8/66	23y	F	0.4	0.010	
79	Medium	12/66	2y 6m	F	1.5	0.011	
52	"	8/66	3y	F	2.1	0.036	0.046
72	"	11/66	3y	F	1.5	0.013	
41	"	6/66	3y 6m	F	2.4	0.020	0.069
83	"	11/66	5y	F	1.5	0.016	
44	"	6/66	7y	F	2.0	0.006	0.048
47	"	7/66	7y	F	2.3	0.013	0.037
56	"	8/66	7y	F	1.5		
80	"	12/66	7y 9m	F	2.1	0.021	
62	"	8/66	8y	F	1.4	0.016	
81	"	11/66	8y 8m	F	1.4	0.030	
61	"	8/66	9y	F	1.4	0.014	
53	"	8/66	9y	F	1.3	0.022	0.054
65	"	9/66	9y	F	1.3	0.142	
76	"	11/66	9y	F	1.0	0.020	
84	"	12/66	10y 7m	F	1.2	0.029	
73	"	11/66	12y	F	1.2	0.016	
59	"	9/66	13y	F	1.2	0.017	0.119
60	"	8/66	14y	F,V	1.2	0.013	0.087
51	"	8/66	14y	F	1.1	0.024	0.038
87	"	12/66	14y 7m	F	1.0		
63	"	8/66	15y	F	1.1	0.010	
78	"	12/66	15y	F	1.8		

TABLE 13 (continued)

Sample No.	Rainfall Area	Date of Death	Age at Death	Bone	Strontium-90 pCi/g Ca	Radium-226 pCi/g ash	Lead-210 pCi/g ash
55	Medium	8/66	16y	F	1.7		
50	"	10/66	16y	F	0.9	0.030	0.067
75	"	11/66	16y	F	0.9	0.014	
77	"	12/66	16y	F	1.0	0.010	
38	"	6/66	17y	F	1.0	0.021	0.047
82	"	11/66	17y	F	1.1	0.033	
70	"	10/66	18y	F	1.0	0.038	
64	"	7/66	19y	F	0.9	0.018	
45	"	6/66	20y	F	0.9	0.010	0.046
57	"	7/66	22y	F	0.6	0.011	0.071
48	"	8/66	22y	F	0.6	0.010	0.042
69	"	10/66	22y	F	0.8	0.013	
40	"	6/66	24y	F	0.5	0.012	0.073
54	"	8/66	25y	F	0.4	0.019	0.042
85	"	12/66	27y	F	0.2	0.012	
39	"	6/66	31y	F	0.5	0.016	0.093
67	High	8/66	14y	F	2.4	0.017	
37	"	5/66	17y	F	1.0	0.014	0.058
66	"	8/66	17y	F	1.4	0.016	

Age at Death: y year, m month, SB stillborn

Bone: F femur, H humerus, L long bones, V vertebrae, R rib, S skull

* Occupationally exposed to luminizing materials.

** Resident in New Zealand a very short time - most of life spent in Australia.

11. Radionuclides in Shell Fish and Seawater

Oysters sampled at various places in the Bay of Islands, New Zealand on 28 September 1970 and seawater from the same areas have been measured for their radionuclide content. The samples have been measured for gross beta activity and also for specific radionuclides by the following techniques:

Strontium-89 and Strontium-90: Radiochemical separation and measurement.

Caesium-137, Ruthenium-103, Cerium-144, Iodine-131, Zirconium-95 and naturally occurring Potassium-40: Gamma Spectroscopy.

Iodine-131 (half-life 8 days) was not detectable in any sample. This nil result was anticipated because the last nuclear test of the 1970 series of French tests occurred on August 7, and levels in New Zealand milk had fallen below the minimum detectable level (2 pCi/litre) at all stations by the end of September.

The levels of gross beta activity in all samples was accounted for by the presence of natural potassium and the traces of fallout material found. There was considerable variability in the gross beta activity of the seawater samples, however, depending on the salinity of the samples i.e. the proportion of fresh and salt water in individual samples. In no sample did the level of natural potassium reach the average value for seawater i.e. 380 mg/litre.

Since there are no nuclear reactors in New Zealand and no radioactive effluents of any sort discharged into the harbour it was anticipated that no radioactivity other than fallout or naturally-occurring radioactivity would be found. This was confirmed by the results of the measurements as tabulated in Table 14.

These results show that the levels of radionuclides in the oysters measured were lower than or comparable with those to be found at those northern hemisphere sites similarly uncontaminated with radioactive effluents.

Measurement

All samples of oysters and seawater were measured individually and there was little variability in the levels of any particular radionuclide (other than naturally-occurring potassium in the seawater samples). The average levels are presented in Table 14.

TABLE 14 LEVELS OF RADIONUCLIDES IN OYSTERS AND SEAWATER

Radio-nuclides	Oysters pCi/g		Seawater pCi/litre
	Measured Levels	Radiological Guide Levels (50 g/day intake)	Measured Levels
^{89}Sr	< 0.003	40	< 2
^{90}Sr	< 0.0003	4	< 0.2
^{137}Cs	0.016	300	Not Detectable
^{103}Ru	0.150	1000	" "
^{144}Ce	0.200	100	" "
^{131}I	Not Detectable	2	" "
^{95}Zr	" "	900	" "

Note:

Although ^{137}Cs, ^{103}Ru and ^{144}Ce were not detectable in seawater they were detectable in oysters because of the concentration factors involved.

Evaluation of Total Intake of Radioactivity in Oysters

The following computation demonstrates that the total radioactivity in the oysters is less than 1% of the Radiological Guide Level* based on a daily intake of 50 g.

$$\left(\frac{0.003}{40} + \frac{0.0003}{4} + \frac{0.016}{300} + \frac{0.150}{1000} + \frac{0.200}{100}\right) = 0.0024$$

i.e. 0.24%

Since the computed value is very much less than unity the radioactivity of the oysters is well within the criteria established by this guide.

12. Radionuclides in Meat Extract

At the request of a local manufacturer, a sample of meat extract was evaluated for strontium-90 and a certificate was issued. The level of strontium-90 was below the limit of detection i.e. less than 1.0 picocuries of strontium-90 per kilogramme at the 95% confidence level.

Caesium-137 and potassium were also evaluated by gamma spectroscopy. The levels measured were:

caesium-137	61 picocuries per kilogramme
potassium	3.95 gram per kilogramme.

These levels are typical of those found in similar types of environmental samples and do not constitute a health hazard.

* This guide level was developed by the National Centre of Radiological Health, Public Health Service, U.S.A. for radionuclides in shell fish. Guides for ^{89}Sr and ^{137}Cs were not given in the Public Health Service tables but have been derived at this Laboratory by the use of the same concepts.

E R R A T U M

TABLE 6 NRL-F/39:

Tarawa 5 June to 12 June:

Change total beta activity to 1.51 mCi/km^2

Change average daily deposition to 0.21 pCi/litre

Monthly total 29 May - 3 July now reads:

total beta activity 7.70 mCi/km^2

concentration 82 pCi/litre

Samoa 6 June to 13 June:

Change total beta activity to 2.09 mCi/km^2

Change average daily deposition to 0.30 pCi/litre

Monthly total 2 June - 4 July now reads:

total beta activity 29.51 mCi/km^2

concentration 132 pCi/litre

Correct the graphical presentation of average daily deposition in the four preceding quarterly reports for 1970 on pages 25, 25, 19 and 15 respectively. The correction has been made in this report (Fig.5).

ACKNOWLEDGEMENT

Work Done on Collection of Samples

The assistance of the Director of the New Zealand Meteorological Service (Dr J.F. Gabites) and his staff of observers has made it possible to:

1. Obtain gamma radiation dose rate measurements several times each day at 6 Pacific Islands from the monitoring instruments installed by this Laboratory;
2. Obtain daily air filter samples at 4 Pacific Islands and at 3 New Zealand stations from the air samplers installed by this Laboratory;
3. Obtain weekly rainwater samples at 13 collecting stations;
4. Obtain monthly rainwater samples at 2 Pacific Islands and at 6 collecting stations in New Zealand.

The co-operation of the Directors of Health at Apia, and of Medical Services at Suva, and their staff has made it possible to extract radioiodine locally from fresh milk by resin column procedures thrice weekly and despatch these samples to Christchurch for measurement.

Officers of the New Zealand Department of Health assisted in obtaining thrice weekly milk samples from 7 towns.

Weekly samples of cattle thyroids are obtained through the assistance of the Department of Agriculture's meat inspection service at 8 collecting stations.

Additional samples are obtained through the assistance of the Soil Bureau, Geological Survey, and Fruit Research Orchard of the Department of Scientific and Industrial Research, from pathologists, from a number of privately operated milk processing plants and from the Department of Health.

Work Done Within the Laboratory

Mr J.F. McCahon, Principal Radiation Officer, was responsible for establishing the relationship between gamma radiation dose rate and potential health hazard, on which the operation of the gamma radiation monitors in the Pacific Islands is based. The monitors were calibrated by Mr L.J. Tucker.

Maps and graphs for this Report have been drawn by Mr A. Stockdill.

All measurements of gross radioactivity and specific radionuclides were made in the low level environmental section of this Laboratory:

(a) All arrangements for sample collection, radiochemical procedures, and measurements of alpha and beta radioactivity are under the control of Mr L.P. Gregory, Principal Radiation Officer, who is also responsible for the editorial work in the preparation of this series of reports. Professional assistance is given by Mr T. Baltakmens, and technical assistance by Mr R.H. Chapman and Mr A. Stockdill.

(b) Gamma ray spectroscopy is under the control of Mr H.J. Yeabsley, Deputy Director. The measurements are made by Mr J.E. Dobbs, Technical Officer.

G.E.ROTH
DIRECTOR