# MANOMET BIRD OBSERVATORY

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Research and Education in Environmental Biology

CONTRACT EY-76-S-02-2308*001

# AVIAN RADIOECOLOGY ON A NUCLEAR POWER STATION SITE

FINAL REPORT

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ABSTRACT

The final report of a six-year avian radioecology study is presented. A complete historical summary is followed by a description of mathematical models developed to calculate the effects on bird body burdens of various changes in environmental radionuclide levels. Examples are presented. Radionuclide metabolism studies in which acute doses of $^{131}I$ and $^{137}Cs$ were administered to four species of wild birds are reported. Radionuclides were administered both intravenously and orally; no apparent differences in uptake or elimination rates were observed between the two methods.

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# I. INTRODUCTION

This is the final report of the work performed under USERDA SRSA #EY-76-S-02-2308*000. The report consists of (a) a historical summary of the entire research program, (b) a detailed report of the research activities during the period 1 July, 1975 to 31 October, 1976, and (c) a brief description of the follow-on work performed under a grant from the General Services Foundation. Although the historical section necessarily repeats much that has been presented in previous reports, it provides a single continuous exposition of the program and was thus felt to be useful.

Notification that ERDA funding support would be terminated at the close of FY'76 led to major shifts in the emphasis of the research effort. Because we felt that the techniques developed in this study have significant potential as a broadly applicable system for radionuclide monitoring of ecosystems throughout the nuclear fuel cycle, we considered it imperative to establish the metabolic response parameters of our primary avian study species for a wide range of potential reactor release products. This knowledge is necessary in order to make possible the linking of avian environmental radionuclide levels to transient radionuclide phenomena in the general environment.

To that end, all field work was terminated on 1 April, 1975, and all remaining efforts and funds were applied to the metabolic studies. Monetary savings from the termination of field activities allowed a stretch-out of laboratory activities through 31 October, 1976. A no-cost contract extention was granted to cover this additional period.

Laboratory studies of radionuclide metabolism in wild birds held captive in our holding facility were performed for two nuclides ($^{131}I$ and $^{137}Cs$) in four avian species. A total of eighty-two birds were given precisely measured doses of radionuclides and held for subsequent remeasurement for up to forty days. Droppings were collected and measured, as were eggs in the case of gravid females. Some specimens were collected and dissected for radionuclide distribution analysis. This work was a logical continuation of the $^{137}Cs$ elimination rate work performed earlier using naturally occurring body burdens, as reported in the FY'75 Technical Progress Report.

## II. HISTORICAL SUMMARY OF THE PROJECT

### A. December, 1970 - June, 1973

#### 1. Initial Proposal

Late in 1970 the Manomet Bird Observatory was approached by the Boston Edison Company which expressed an interest in a proposal for any environmental study to be performed on the site of and in conjunction with Edison's first nuclear reactor then under construction on a site 3km from the Observatory. Although other research organizations had been engaged to perform legally-mandated monitoring studies, the invitation to submit a proposal presented an opportunity to investigate the integration of MBO's skills and expertise in ornithology with the established needs of a growing industrial technology.

The Observatory responded with a proposal to make a long-term study of environmental radionuclides by means of repetitive non-destructive gamma-spectroscopy of wild birds resident on the power station site. We knew that multiple recaptures of local birds, each uniquely identified by banding was a frequent occurrence and that birds have a high survival probability after their first year. In addition, food habits and territory sizes of common species had been studied extensively. This meant that we could repeatedly access identified individual birds over a period of up to fifteen years. Previous research would allow the determination of food sources and ranges of movement. Study of the area bird populations and densities, and of the food habits of locally common species indicated that a statistically significant sample of birds with a wide range of food inputs was obtainable.

In May, 1971, Boston Edison funded the proposed study.

#### 2. Selection of Trapping Sites

Initial surveys of the site of the Pilgrim Nuclear power station were performed during June, 1971. Studies of terrain and vegetation types were made. Two primary sites were selected as shown in Figure 1. Located in similar environments, one site was approximately 275m

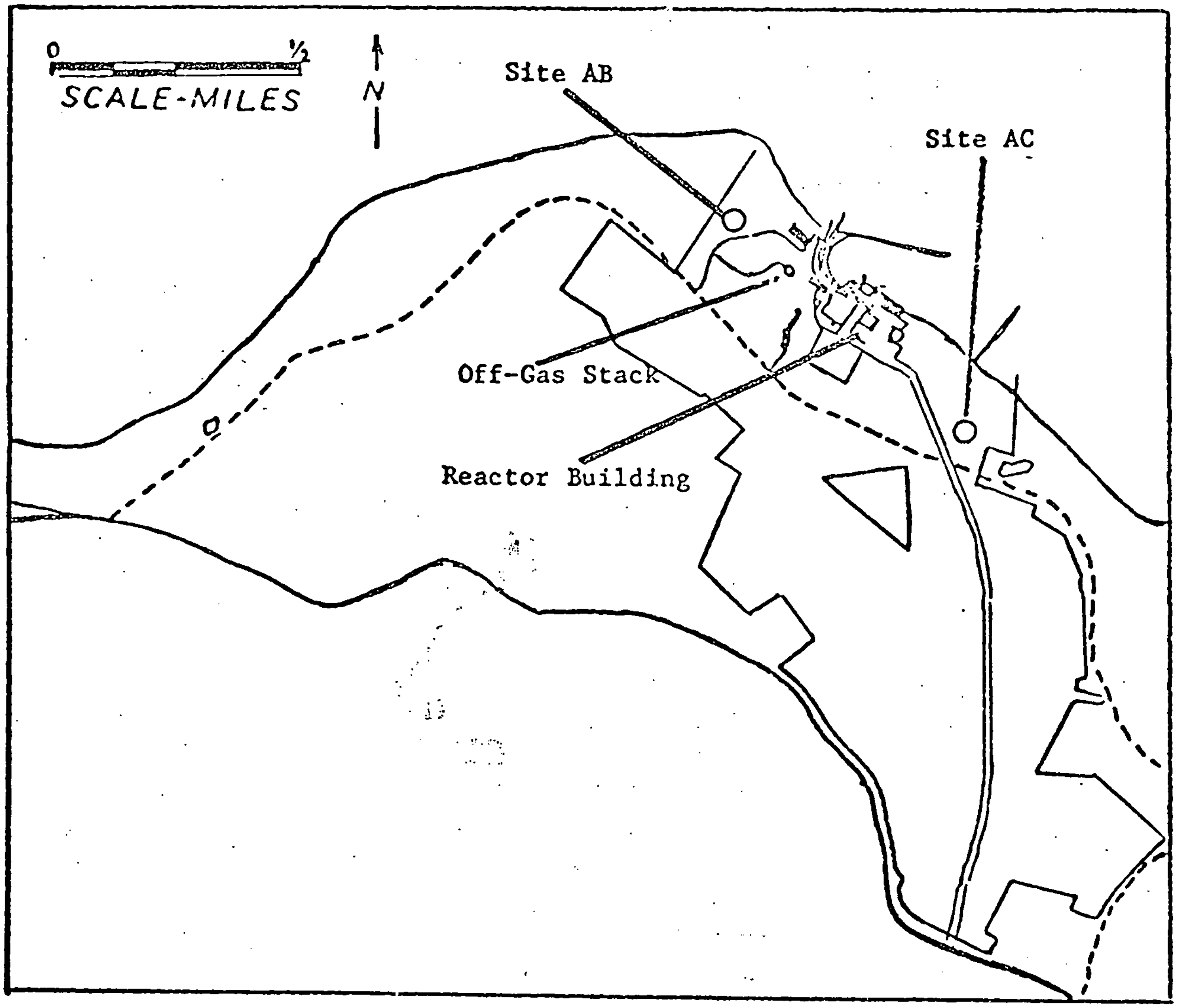


**Figure 1.** Reactor Station Trapping Sites

WNW of the off-gas stack, the other about 500m ESE of the stack. The western site nets were oriented approximately N-S and extended to the bluff at the water's edge. The other site line was oriented SW-NE and came to within about 60m of the water's edge. The vegetation at both sites typified the second growth shrubby deciduous cover found in many areas of the New England coastal plain. The nets themselves were located on abandoned dirt roadways which had a maximum clear width of less than 3 meters. Canopy height at the power station sites varied along the net lanes from about 2 to 6 meters. The fact that the terrain and vegetation at the selected net sites was quite similar to that at the Manomet Bird Observatory site was considered advantageous in that certain predictions could be made regarding the species likely to be netted.

Each selected site was fitted with permanent net-support poles. Twelve 12X2 meter nylon mist nets, primarily NEBBA type ATX[1], were used at each site, placed in groups of two with a three to six meter spacing between each group. Each net lane was about 75m long. Minimal clearing was performed to prevent large branches from snaring the open nets, but no further alterations were made to either site.

After the selection of the primary netting sites, a search was initiated for an appropriate control site. It was required that the control site be sufficiently removed from the power station site such that the likelihood of interaction was highly remote, and that the terrain and vegetation be as similar as possible. Approximately 21km south of the Pilgrim Nuclear Power Station site at the entrance to the Cape Cod Canal lies the Scusset Beach State Reservation. Extensive parts of this reservation are closed to public access, and in one of these sections we were able to set up a 75m-long net lane along a little-used mosquito-control road. The elevation of this site, which is oriented E-W, is somewhat greater than the primary sites, and the distance from

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1. The NEBBA type ATX mist net is a black nylon net made from 70 denier monofilament in a 36mm mesh pattern, tethered, with four levels or "shelves".

the shorefront in also greater (about 900m), but the vegetation types and densities were found to be quite similar. As at the primary sites, twelve 12X2 meter mist nets were used. The location of this site, labeled "AD", is shown in Figure 2.

Since a primary goal of this research program has been to make multiple recaptures and remeasurements on identified individual birds, the trapping procedures were implemented in such a way as to maximize repeats, i.e., multiple recaptures over time. In order to minimize net shyness (the tendency for birds to avoid net locations after frequent captures) each net site was opened for only one twenty-four period each week. The six-day gap with no open nets allowed the birds to forget the nets.

3. Bird Handling Procedures

The procedures for handling trapped birds were developed with the twin goals of population survey and radionuclide study in mind. Although only a fraction of the birds trapped were used as whole-body counting subjects, all birds were banded. Banding was done at the net site. Complete banding data were recorded at the time of capture. The records were taken using the MBO Standardized Banding Record Sheet (Salvadori & Youngstrom, 1973). Birds other than those selected for radionuclide measurement were then released. The remaining birds were periodically taken back to the whole-body counting laboratory at MBO where they were transferred to multiple-cell holding boxes which carried data sheets indicating band number, species, trapping location, and repeat status. At the completion of the whole-body counting procedure the birds were taken back and released at the site of capture. Although it is likely that most birds would have returned to the trapping site even if they had been released at the MBO laboratory, they were always returned to the capture site to maximize repeat probability. The total holding time for birds sent to the radionuclide measurement laboraotry was as little as two hours, although the average was about six hours. In some cases, due to the onset of darkness, birds were kept over night. Program policy was that any birds with existing or receeding brood patches

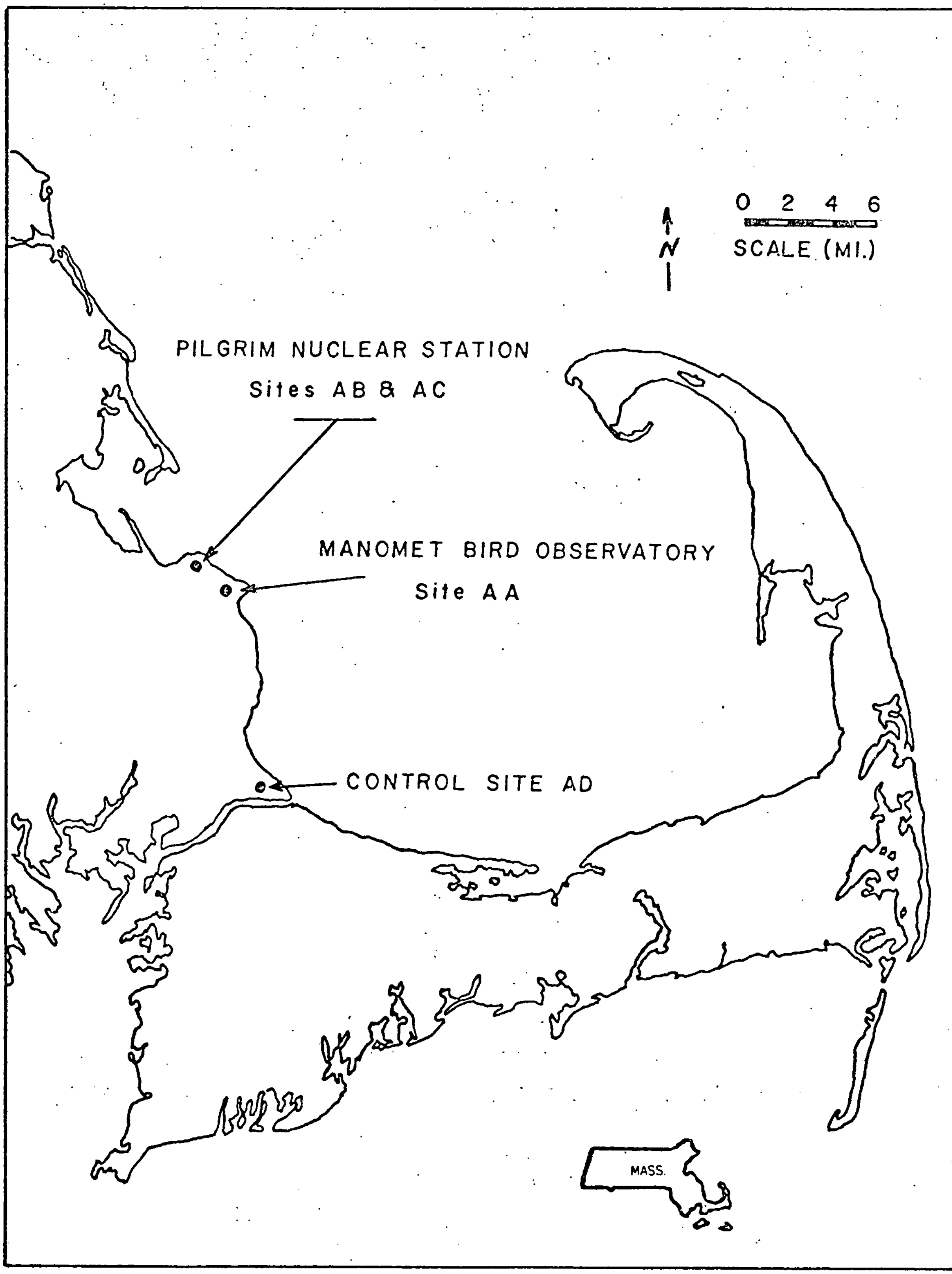



Figure 2. First Control Site Location

were not held for measurement, but were released after banding.

4. Other Sample Sources

In addition to the birds acquired through the operations of the promary and control netting sites, samples were obtained in several other ways. The normal banding program at the Observatory provided access to large numbers of birds. Cooperation with personnel of the Massachusetts Division of Fisheries and Game enabled us to access samples from many of their field activities. Their banding programs included work with Black Ducks, Ruffed Grouse, and Mourning Doves. The same personnel were cooperative in supplying us with dead specimens, generally road kills or birds seized for use as evidence in game-law violation cases. The regional Federal game-law enforcement representative was also an excellent source of such material. With these samples we were able to make measurements on many species which would have been difficult to obtain in any other way. For example, the trapping of many species of waterfowl requires specialized techniques which are often expensive and time consuming. By sampling dead specimens we were able to make informed judgements as to the desirability of engaging in the specialized efforts required to live-trap these species in accordance with the radionuclide measurement results.

5. Radionuclide Measurement Laboratory Construction

Primarily due to the weight of the whole-body counting chamber, and to allow for possible additional shielding, or additional counting equipment, the whole-body counting facility was located in the basement of the Observatory's principal building. The major drawback of this location, granite foundation walls with their attendant problem of radon emission, was immediately recognized. However, structural limitations demanded the use of this location and design steps were taken to minimize the background effects from the radium decay products. The laboratory walls were constructed of carefully sealed gypsum wallboard backed by fiberglass insulation with a foil vapor barrier. This construction was in turn sealed with a further polyethylene vapor barrier. Wall junctures were sealed with a double caulking seal. Finally, the walls were spaced a minimum of 15cm from the foundation walls to allow the independent circulation of air within the inter-wall spaces. Air for the laboratory spaces themselves is drawn in from outside sources. The laboratory floors are reinforced poured concrete with a minimum thickness of 10cm, and a thickness of 75cm in the support areas for the whole body counter.

Environmental controls allow the laboratory spaces to be maintained at a temperature within $\pm$ 1°C of that selected and at a relative humidity of 50 $\pm$ 10%. Power is supplied by two 2.5kva 120VAC lines and one 1.0kva 118VAC stabilized harmonically filtered line.

## 6. First Whole-body Counter

The whole-body counter used during the first part of the research program consists of a double-walled steel form with an interstitial shielding fill of 5cm of poured lead. Graded inner shields of copper and aluminum are used to minimize the effects of K X-radiation from the lead. A horizontally-swinging door of similar construction gives access to the upper portion of the chamber. All materials used in the construction of the cave were radioassayed prior to use.

The internal dimensions of this first chamber are 41cm wide by 51cm deep by 69cm high. The chamber is divided approximately in half horizontally by a shallow V platform used to support the sample holders. Initially, the entire chamber was pressurized with air drawn through a 0.5 micrometer filter to remove the solid radon daughters arising from the granite used in the building construction. This air system was later modified during the installation of the second counting system

Detectors used in this system are two 7.5 X 7.5cm Harshaw Integral Line NaI(Tl) crystals fixed at a 60° included angle beneath the sample support platform. Although this does not represent optimum geometry, the entire system was originally designed to be operated by unskilled personnel and a variable geometry mount was considered to be too error prone. The samples for counting are carried in cylindrical Lucite containers. Four sizes of these containers were fabricated; these four accomodate birds weighing from a few grams to several kilograms. The use of these containers allows the accurate and repeatable placement of the specimens in relation to the detectors, restraint of the specimen, and maintains chamber cleanliness. Perforated end caps on the sample holders allow air to reach the bird being measured. It should be noted that the birds do not struggle or attempt to escape while in the chamber. In general, when placed in a dark environment, a bird becomes quiescent. To extend the utility of this phenomenon, the counting room is equipped with dim red lights which can be used in place of the normal lighting when it is desired to maintain this quiescent state outside the chamber.

The output signals from the chamber's two NaI(Tl) detectors are "teed" and led to the amplifier input of a Northern Scientific (Tracor) NS-710 1024 channel pulse-height analyzer. Coupled to the analyzer is a Northern NS-450 data processor which allows data manipulation functions including background subtraction, spectrum stripping, curve smoothing, etc. to be performed on the data stored in the memory of the PHA. The I/O device for the system is an ASR-33 telytype. All sample spectra are read out as raw data on punched paper tape for storage and later analysis or comparison. Read out in printed form are raw spectra, integrated area counts of selected energy regions centered about the gamma peaks of the radionuclides for which the system is calibrated, and integral counts of the same areas after background subtraction.

The calibration of the whole-body counting system proved to be somewhat of a problem; except for domestic-fowl phantoms, bird phantoms are quite rare. There was little reference in the literature to bird phantoms, nor was there much data on elemental distributions in small birds, and no similarities could necessarily be assumed with mammals. One factor making normal mammal phantoms completely unsuitable for bird studies is that birds are, on the average, only about one-sixth the density of the average mammal. This density difference also means that one is unable to get as much bird mass within given geometric limitations as one could with a mammal of similar size, thus losing effective sensitivity in whole-body counting. For the initial phases of this research program it was decided to use phantoms of appropriate density with uniformly distributed radionuclide loadings. Four representative species were chosen as birds likely to be handled in our field operations. These design birds weighed 5, 85, 450, and 1500 grams, and were, respectively the Kinglet, the Robin, the Fish Crow, and the Black Duck. Outline drawings were prepared for each bird to assist in the preparation of the uniform distribution phantoms using appropriate weight data.

These phantoms were subsequently placed in the appropriate Lucite sample carriers and positioned in the whole-body counter. Sensitivity calculations were based on repetitive series of phantom counts long enough to ensure statistical validity of the data. The energy range used for the accumulation of data in the PHA was 30KeV on either side of the gamma peak energy. In the case of nuclides with multiple gamma peaks, the most prominent was selected. The PHA was programmed to sequentially print out the total counts in the energy regions of interest as well as intensifying these areas on the visual display. Thus, a very rapid visual screening of the data could be performed and unusual peaks became readily apparent on the CRT display. The phantoms were also used to generate background-stripped data tapes which could be used together with the manipulative subroutines of the NS-450 data processor to perform spectrum stripping.

The total background counting rate for the first whole-body counting system is about 1150CPM over the energy interval from 0.2 to 2.56MeV. The nuclides for which this system was initially calibrated include $^{54}$Mn, $^{60}$Co, $^{65}$Zn, $^{95}$Zr-$^{95}$Nb, $^{131}$I, and $^{137}$Cs. For our calibration, the $^{95}$Zr-$^{95}$Nb was assumed to be in equilibrium. System detection limits for this first system are listed in Table 1. This table presents data in terms of minimum detectable radionuclide activity ($2\sigma$ above background) and radionuclide body burdens for each size class. The detection limits are for one hundred minute counts.

Table 1. **Whole-Body Counting Limits**[1]

| Nuclide | Size Class | Detection Limit[2] (pCi) | Equivalent Body Burden[3] (pCi/g) |
|---|---|---|---|
| $^{131}I$ | I | 5.45 | 1.09 |
| | II | 8.10 | 0.10 |
| | III | 16.0 | 0.04 |
| | IV | 22.4 | 0.02 |
| $^{137}Cs$ | I | 8.62 | 1.73 |
| | II | 15.9 | 0.19 |
| | III | 21.6 | 0.05 |
| | IV | 34.5 | 0.02 |
| $^{95}Zr$-$^{95}Nb$ (4) | I | 2.46 | 0.49 |
| | II | 4.11 | 0.05 |
| | III | 6.57 | 0.02 |
| | IV | 10.5 | 0.007 |
| $^{54}Mn$ | I | 7.36 | 1.47 |
| | II | 11.3 | 0.13 |
| | III | 18.9 | 0.04 |
| | IV | 37.5 | 0.03 |
| $^{65}Zn$ | I | 31.7 | 6.34 |
| | II | 43.0 | 0.51 |
| | III | 69.9 | 0.16 |
| | IV | 114.1 | 0.08 |
| $^{60}Co$ | I | 11.8 | 2.35 |
| | II | 15.8 | 0.19 |
| | III | 27.1 | 0.06 |
| | IV | 45.4 | 0.03 |

1. Based on 100-minute counts of uniformly distributed avian phantoms.

2. Detection limit is defined as that activity which produces 2 $\sigma$ counts above background

3. Equivalent body burden for design weight bird; Class I = 5 g, Class II = 35 g, Class III = 450 g, Class IV = 1500 g

4. $^{95}Zr$-$^{95}Nb$ assumed in equilibrium

7. Laboratory Procedures

In the whole-body counting laboratory a minimum of 25 consecutive background counts are taken each week. From these data the mean and standard deviation of background count rates in each energy area of interest is calculated. This information is recorded on a weekly data sheet and any significant deviations from the previous week's data and from a continually accumulated mean of these weekly means would be investigated. Background stability has been such that the only significant deviations which have occurred have involved occasional spurious peaks due to cable connector noise, and these problems have been readily rectified. Preparations for daily operation involve an energy calibration check of each detector separately using a $^{226}Ra$ source, and a resolution check of both detectors using a $^{137}Cs$ source. A 100-min background count is made, punched out on paper tape for reference storage, and, finally, this same background count, after examination for deviations from previous accumulated count data, is stored in the PHA memory for subtraction from bird counts during the day. If the sample load allows, new 100-min backgrounds are taken and used between bird specimens throughout the day. Figure 3 shows a 1000-minute background from the two-detector counting system.

Avian samples are placed in the chamber for measurement, and pertinent identifying data is punched on the paper tape header and printed on the TTY sheet. This information includes band number (or an identifying code in the case of dead specimens), species, weight, sample size class, date, time, count duration, and trapping location. During these early phases of the research program, the sample spectrum was accumulated in the first quarter of the PHA memory, using only 256 channels. After the first fifteen months, PHA calibrations were changed so that the energy resolution was exactly doubled, and the sample spectra were accumulated in the first half of the memory, using 512 channels. At the completion of the count, the data in the first quarter of the memory

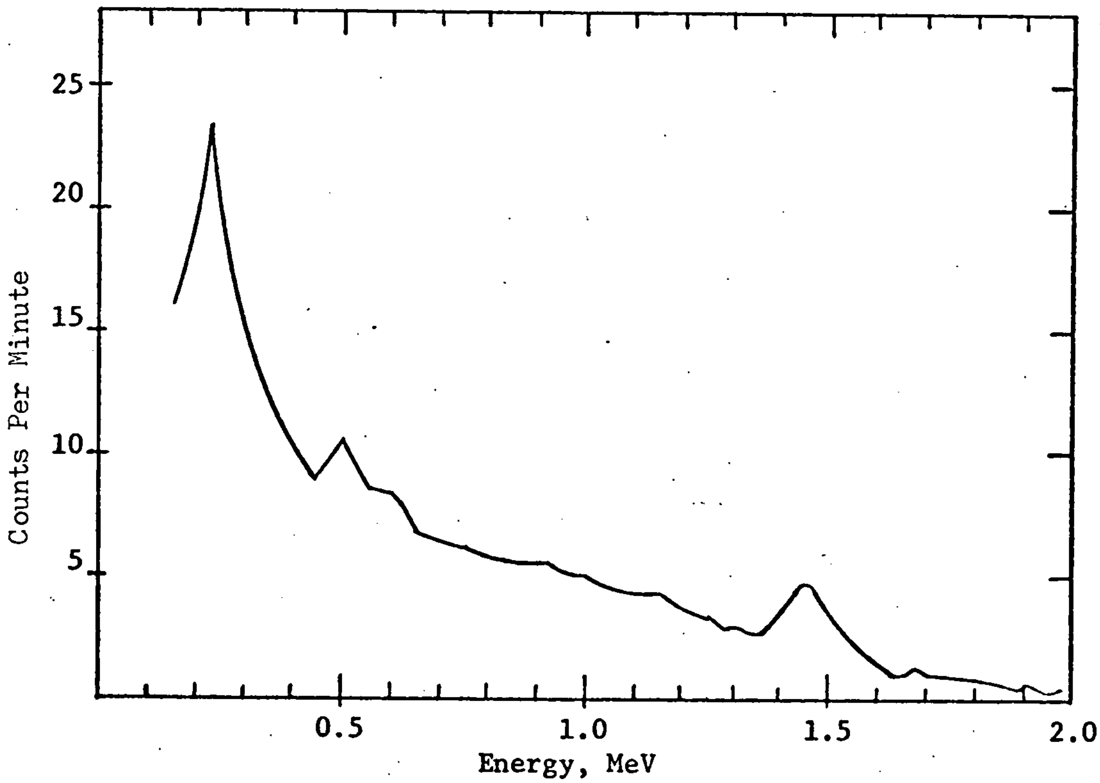



Figure 3. 1000-minute Background Spectrum, Two Detector System

(the total spectrum) was duplicated in the second quarter. The stored background in the third quarter was subtracted from the data in the second quarter, leaving the raw spectrum in the first quarter and the background-stripped spectrum in the second. The total raw spectrum was then printed and punched out on paper tape while the integrated areas from both quarters were printed out only. The listing of integrated areas from the first quarter (total spectrum) could be compared with listings of similar areas from the consecutive backgrounds pool, and the areas printed out from the background-stripped spectrum indicated deviations from the most recently taken background. Thus a quick assessment could be made of (a) deviations from long-term background averages, and (b) from the most recent background. Areas showing total or differential counts more than 2SD above tabulated background were reduced to body-burden data using the phantom-derived calibration information.

8. Early Field Operations

During the first year of the program's operation the field staff banded more than 2,000 birds of 88 species; 418 birds were handled more than once, i.e., were repeats. Examining the banding data and selecting out the obvious migrants, initial data on repeat frequency of residents indicated that our predictions concerning access to a stable, long-term population were probably to be justified. Depending on species, the data indicated repeat ratios of 0.4 to 0.8, i.e., that we had a 40 to 80% probability of making multiple recaptures of any given bird. It was felt that the ratios would have been even more favorable had it not been for an unusually mild winter, as explained below.

Winter sampling depends on the use of baited traps rather than the more productive nets. In a trap baited with sufficient food, a bird safely can spend considerable time in even the coldest weather, whereas, immobilized in a net, death from exposure might be rapid. The use of traps means, of course, the use of bait. Since our research goal was to study birds which derived their sustenance from the food naturally available at the study site, the heavy baiting of traps with food from commercial sources would have resulted in an artificial diet for the sampled birds. We thus depended on the persistent snow cover which is normal in our study area, especially in wooded areas shielded from the direct sun, to conceal natural food sources and make very lightly baited traps attractive to birds. However, the nearly complete lack of snow cover during the winter of this first year made natural food available constantly, and lightly baited traps were not frequented by the birds, thus minimizing the winter captures of resident birds.

In the whole-body counting laboratory, measurements were made on more than 400 birds of 69 species. Dead mammals of ten species were measured. The only radionuclide detected routinely was $^{137}Cs$. The failure to detect other radionuclides which we had reason to expect were present gave the first indications that the sensitivity of our instrumentation might not be sufficient to meet our research goals.

During May of 1972 a number of birds showed easily detectable body burdens of $^{95}Zr$-$^{95}Nb$ which we attributed to the Chinese atmospheric nuclear test of late March, 1972. We were to detect $^{95}Zr$-$^{95}Nb$ routinely after similar tests in the future.

B. July, 1973 to June, 1974

1. AEC Proposal

Early in 1973 a proposal was submitted to the United States Atomic Energy Commission, Division of Biomedical and Environmental Research, requesting that they take over and expand the support of the radioecology project. We recognized that a long-term study was essential and that more sensitive instrumentation would be required. As the initial grant from the Boston Edison Company was understood by all parties to be seed money, that company was unwilling to make the commitment to long-term expanded funding and to the new instrumentation.

The USAEC accepted our proposal and we were thus able to initiate design and procurement of a new, more sensitive whole-body counting system while field work and measurements using the first system continued.

## 2. Second Whole-body Counting System

The new whole-body counter was designed by the project staff in conjunction with the fabricating contractor. Basic layout and performance data were generated by the staff while design, implementation and detailing were the responsibility of the fabricators.* Again, all construction materials were radioassayed prior to use.

The counter is a 48-cm cube fabricated from $\frac{1}{4}$" aluminum plate (6061-T651). Copper sheet 0.8mm thick surrounds the aluminum, and a double layer of standard-sized virgin lead bricks encases the volume in an overlapping joint pattern to produce a minimum thickness of 10 cm. In addition to attenuating low-energy x-rays and gamma-rays, the aluminum acts as the support structure for the lead on top of the counter, for the crystal housings, and the crystal housing shields. A lead door of similar composite construction overlaps the opening at the front and is pneumatically damped.

Four 7.6 X 7.6-cm NaI(Tl) detectors are located in the vertical mid-plane between the front and back faces of the chamber with their axes positioned on the diagonals of the projection of the front and back faces. Each of the detectors can be positioned at various set points on the diagonals to form a symmetrical array about the center of the counter at specific radii. A cylindrical lead housing with poured lead end cap fits over the outside of the counter at each of the four detector mounting positions to provide shielding at these points while allowing the detectors to be positioned with a detent arrangement at standard positions. Placing the detectors on the diagonal allows almost the same ease of access to all the detectors for positioning, prevents inadvertent slipping of the detectors during positioning by the friction developed at the $45^{\circ}$ angle, and provides open space between the two lower detectors so that anything dropped will not strike the detectors.

In order to ensure the lowest possible background, the detectors used in this system used low-noise photo tube assemblies, and a 5-cm thick unactivated spacer (NaI) was encased between the active crystal

* Bio-Nuclear Measurements, Inc., Ipswich, Massachusetts

and the face of the PMT.

As in the first whole-body counter, a V-shaped trough which supports the bird holders is located between the two lower crystals. However, in order that the four different sized holders remain centered in the chamber (and thus in the four-crystal array) it was necessary to provide two different troughs and three trough supports to accomodate the holders. Locating slots ensure the rapid and repeatable placement of the proper combination of trough and support for each holder. Physical stops on the troughs provide repeatable longitudinal locating of the holders, while the V-shape of the trough automatically ensures transverse centering. A chord on the end plate of the holders has been cut off as we have found this to provide more effective restraint by allowing the tail of the bird to protrude while effectively restraining the bird's body.

Replacing the earlier described in-lab air pump and filter is a larger compressor unit. Air is now drawn from above the roof of the laboratory building at a height of about 10 m above the ground. The compressor feeds the air to the laboratory where a large cartridge filter removes particulate matter of >0.6 micrometer size with more than 99% efficiency. This filtered air is supplied to both chambers at a rate sufficient to create at least four counter-volume changes per minute.

The second whole-body counting system uses the electronics previously described for the older system. High voltages for the new crystal array is provided from a common supply feeding an adjustable voltage-divider network. Individual PMT voltages are set and monitored using a digital voltmeter. The crystal-PMT array was ordered to an array resolution of <7.5% ($^{137}$Cs.). Experience has shown the average system resolution to be <7.25%.

As compared with our first counting chamber, the new chamber has a significantly lower background count rate, lower residual $^{40}$K count rate, and the expected increase in sensitivity from doubling the number of detectors. Figure 4 illustrates comparative background spectra from

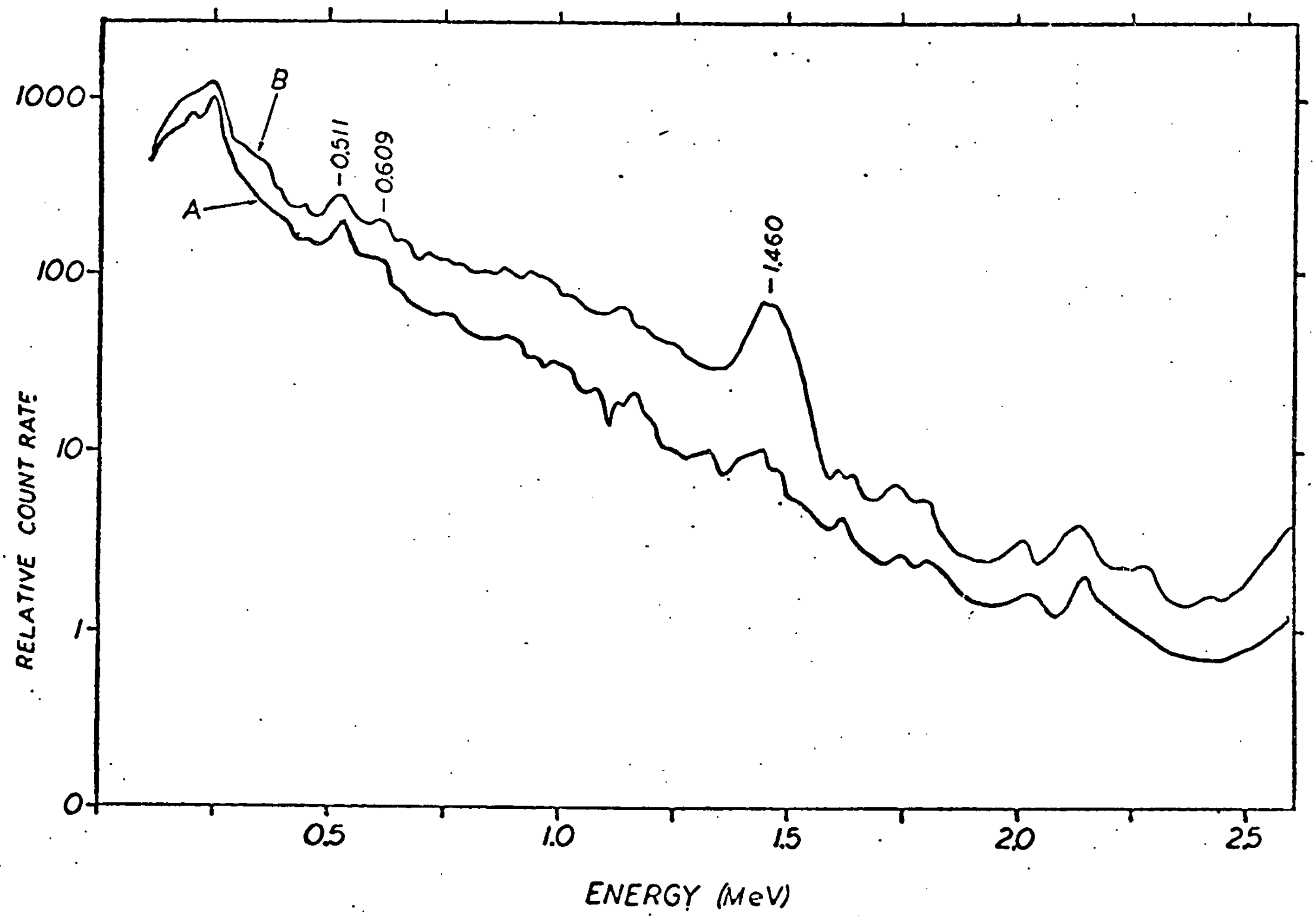



**Figure 4.** Comparative Background Spectra

**Curve A.** New Whole-Body Counter
**Curve B.** Old Whole-Body Counter

the two chambers. Table 2 lists background count rates for various energy regions using the new cave. Note that the count rate varies slightly with detector position in the cave, increasing as the crystals approach each other or the cave walls.

Table 2. Background Count Rates for the New Whole-Body Counter

| Detector Position* | Energy Range (MeV) Lower Limit / Upper Limit | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.25 / 2.50 | 0.305 / 0.335 | 0.345 / 0.380 | 0.640 / 0.690 | 0.730 / 0.770 | 0.810 / 0.855 | 1.090 / 1.140 | 1.150 / 1.200 | 1.425 / 1.495 |
| | CPM | CPM | CPM | CPM | CPM | CPM | CPM | CPM | CPM |
| II | 842 | 41 | 40 | 26 | 19 | 18 | 12 | 11 | 11 |
| III | 875 | 38 | 37 | 24 | 19 | 18 | 12 | 11 | 10 |
| IV | 886 | 48 | 48 | 28 | 23 | 21 | 11 | 11 | 13 |

* Detector position I not used. Position II used for smallest specimens (crystals closest together), position IV for largest specimens (crystals closest to chamber walls).

Sensitivity in terms of radionuclide detection limits was determined to be as indicated in Table 3.

Table 3. System Detection Limits for Second Whole-Body Counter

| Bird Class | Average Weight (g) | Detector Position | Detection Limit it pCi/g (.05 significance level), 100-min count, for: $^{40}K$ | $^{60}Co$ | $^{65}Zn$ | $^{131}I$ | $^{137}Cs$ |
|---|---|---|---|---|---|---|---|
| I | 30 | II | 2.88 | 0.24 | 0.46 | 0.31 | 0.27 |
| II | 100 | II | 0.86 | 0.07 | 0.14 | 0.08 | 0.08 |
| III | 450 | III | 0.44 | 0.04 | 0.07 | 0.05 | 0.04 |
| IV | 1500 | IV | 0.33 | 0.05 | 0.02 | 0.03 | 0.03 |

A $^{226}Ra$ source spectrum taken with the second whole-body counter is included as Figure 5.

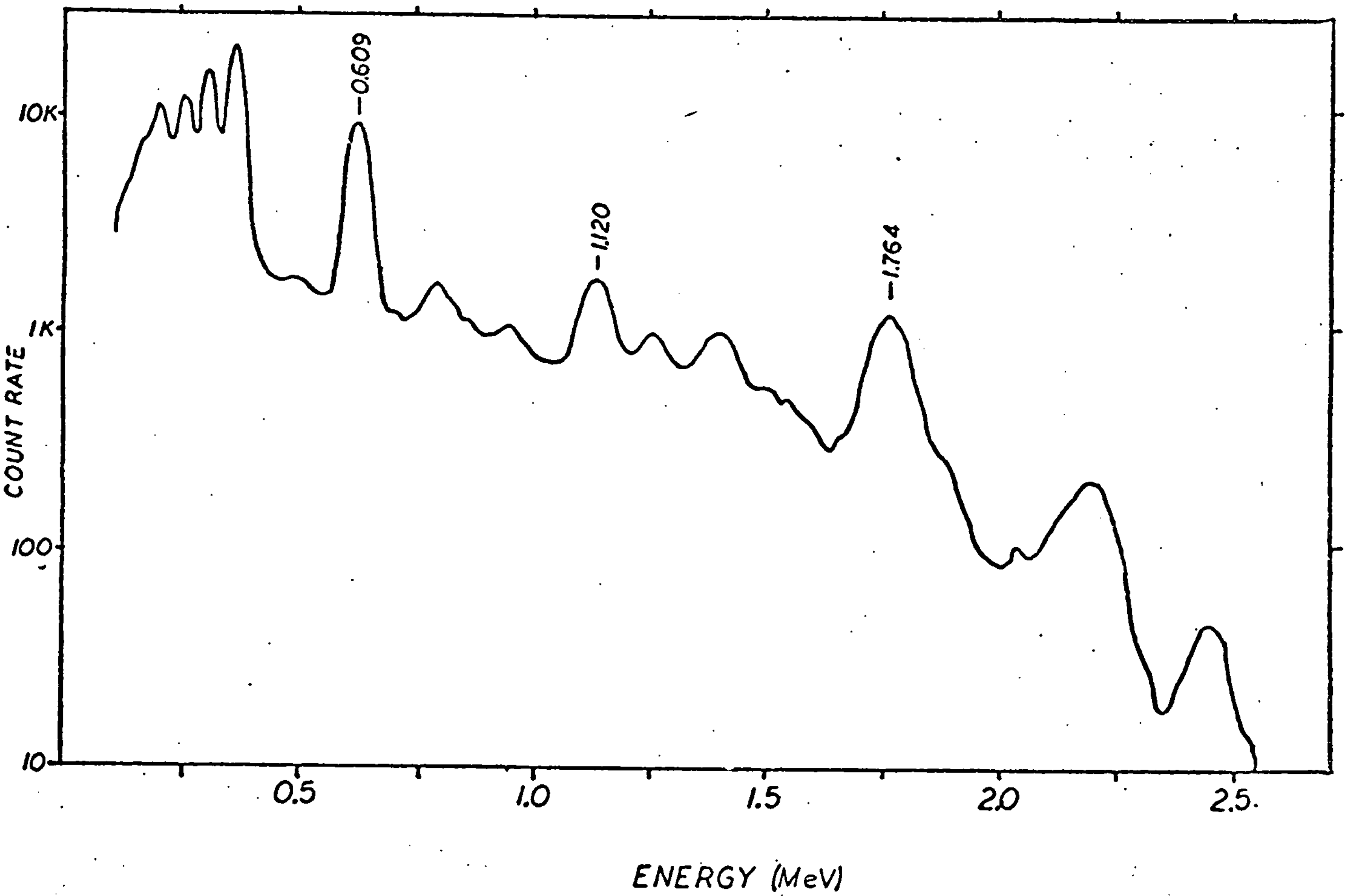



Figure 5. $^{226}$Ra Source in New Whole-Body Counter

3. Trapping Site Changes

The design, construction, installation and testing of the new whole-body counter, together with two periods of PHA downtime (one of which was due to a faulty interface cable supplied with a new point plotter), detracted from the field activities during the 1973-1974 season. In addition, a re-evaluation of the suitability of each trapping site resulted in the suspension of work at one control site, the opening and subsequent closing of a third site on the reactor station property, and the development of a new primary control site, all of which lessened the total of avian specimens processed.

The closing of the original control site at the Scusset Beach State Reservation was necessitated by two factors. Located as it was on a state-owned public beach reservation, a recent opening-up of the area to long-term use by motor campers, although the camper area was removed from the net area, led to an unacceptable increase in vandalism. Although the use of a mosquito-control road necessitated developing a net-support system which was almost entirely removeable to allow the continued use of the road when nets were not in place, the persistence of the vandals in digging out three-foot lengths of iron pipe set flush with the ground (and the filling-in of those pipes which they were unable to dig out) was a factor in the decision to abandon the site. Secondly, the area was coming under increasing pressure from hunters using the reservation during the upland game-bird season, as well as a good deal of illegal out-of-season hunting activity, both endangering the field biologists working at the site. It was with considerable reluctance that we suspended the use of this site since a significant portion of the resident avian population had been banded during the first two years of the program. In addition, its location, immediately adjacent to an expanding oil-fired power generating station made it of considerable environmental interest. However, drawbacks associated with its use made it necessary to abandon the site and seek a more stable control site. Certain net support hardware was left in place at the Scusset site, buried and inconspicuous, so that if it should prove of extreme interest to reopen the site in spite of its problems we can do so and will be able to recreate the exact trapping geometry used in the past.

Taking advantage of the opportunities afforded us by an expanded field biologist staff, it was decided to open a third trapping site on the 517 acre reactor station property. A site was selected to provide a habitat as different as possible from the other two sites on the station in order to access a different avian population, and the necessary nets were put in place. Unfortunately, although prior observation had suggested otherwise, this mixed pitch-pine and white oak habitat proved to be nearly devoid of trappable avifauna. After extensive experimentation, the site was abandoned.

We were fortunate to be offered the use of an area on a large (800 acre), fenced, patrolled, private farm site approximately 20-km south of the reactor site and 6.5-km west of the abandoned Scusset Beach control site. A wide diversity of habitat sites was found at this location and trapping sites were set up during September and October of 1973. Capture results were excellent, and the absolute freedom from vandalism was ensured. Sufficient habitat variation existed at the new control site such that we could orient our activities in a way so as to maximize the catch of any population type determined to be of particular interest. However, the initial sites chosen represented as close a duplication of the power station sites as possible. As at the power station, two twelve-net lanes were set up, the nets being emplaced in groups of two over a 225-m path length.

The Manomet Bird Observatory was also now being used as a control site on a regular basis, especially during the winter months when a trapping program allowed access to a stable resident population of Blue Jays, Bobwhite, and various species of sparrows. During the spring, summer, and fall, the primary goal of the netting program at the Observatory itself is to band the maximum number of migrants. To this end, the nets are generally open twenty-four hours per day. Under these conditions, the resident population quickly learns of the nets and avoids them. We are thus denied repetitive access to the resident population. This shyness factor generally does not apply when using traps, however, so when traps are used in the winter the repeat statistics become favorable at the headquarters site.

Figure 6 shows the location of the abandoned control site and the new control site as well as their relationship to the reactor and the Observatory sites. Figure 7 shows the location of the unsuccessful new site on the reactor station as related to the two principal sites.

4. Specimens Handled, 1973-1974

Notwithstanding the delays and difficulties enumerated above, the project field staff was able to capture and band over 2500 birds during the 1973 - 1974 project year. More than 700 birds were handled more than once for an overall repeat proportion of 0.28. The opening of two new netting sites of necessity diluted the potential repeat population. Eighty-eight species were banded. A number of interesting individuals were banded including two Brewster's Warblers. Many of the Blue Jays banded at the reactor site in 1971 were recaptured during 1973, although very few of these 1971 birds were seen during 1972. There had been a general indication that fewer Blue Jays than normal had been seen in New England during 1972, and our data tended to confirm these observations.

The radionuclide measurement phase of the program suffered somewhat more than the field trapping activities because of the changes in equipment and trapping sites. Even so, 655 avian specimens were measured, representing 44 species. Three hundred and fifty birds were measured for the first time, and 145 of these first-timers were handled at least one more time during the course of the year. Some individuals, their band numbers becoming very familiar, were measured for the sixth or seventh time. Individuals of twenty additional species were measured as dead specimens.

Mammalian speciemens provide a source of additional data and are

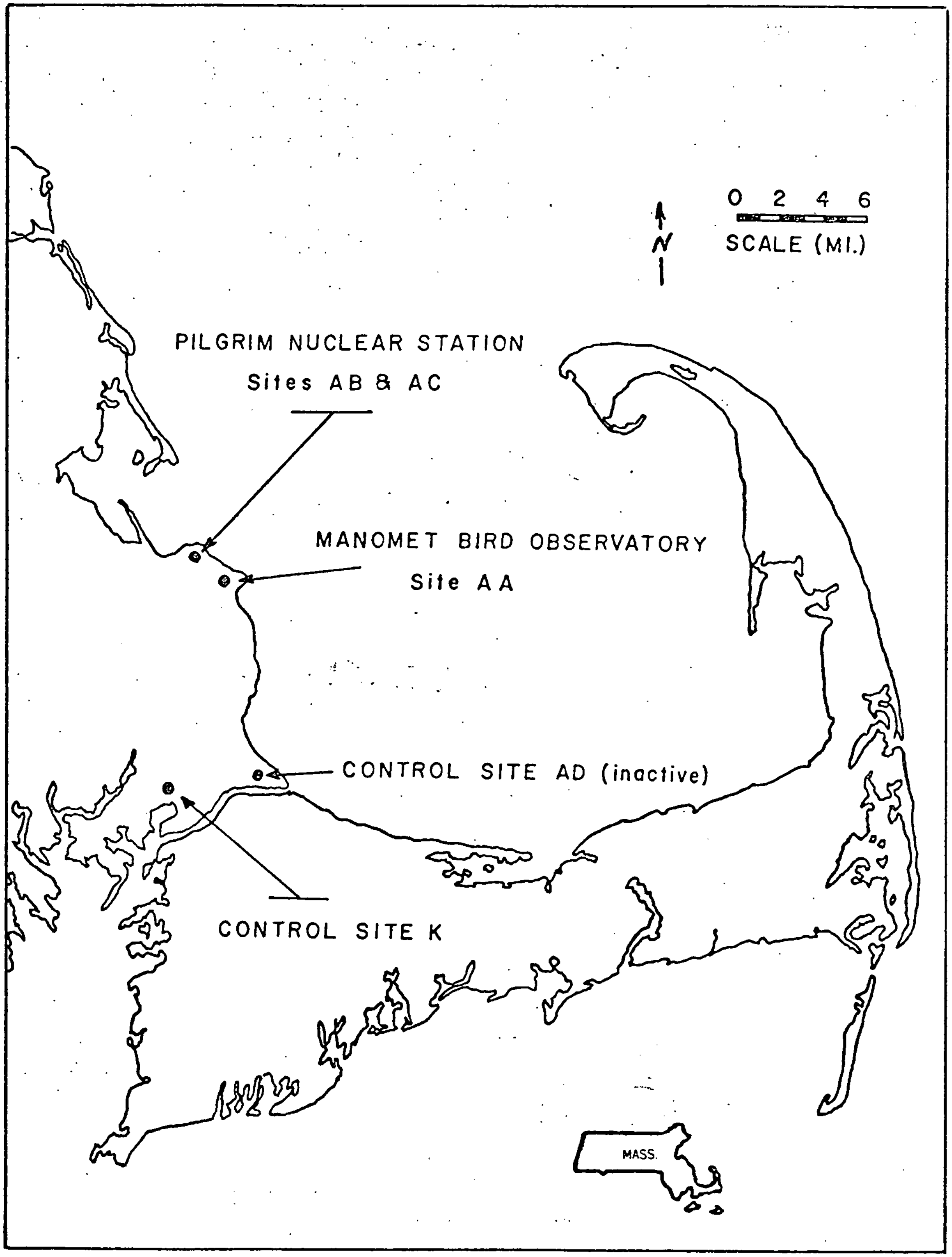



Figure 6. Locations of First (Abandoned) and Second Control Sites

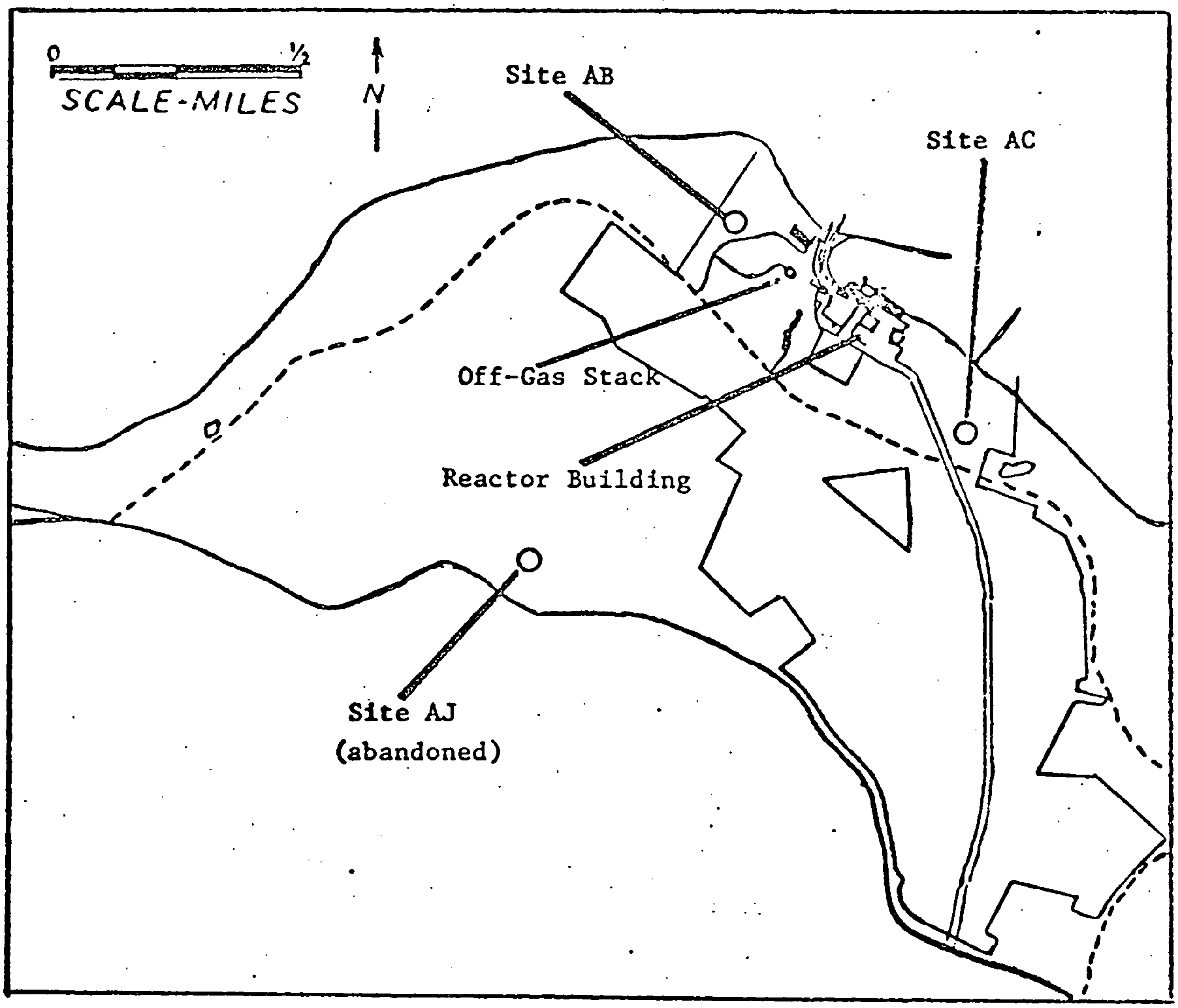



**Figure** 7. Reactor Station Trapping Sites especially useful due to their relatively greater density as compared with wild birds. We therefore continued to measure mammals on a time-available basis. In addition to our casual mammal sampling which consisted mainly of gathering road kills and those small mammals accidentally caught in our ground-level bird traps, a researcher from Boston University conducted a trapping program for an independent woodchuck study which enabled us to access a relatively stable population of this marmot.

## 5. $^{137}Cs$ Levels in Birds

$^{137}Cs$ levels in excess of detection limits were detected routinely in birds from the beginning of the program. However, the detection limits of the original whole-body counter were such that, although we could establish that the $^{137}Cs$ levels were highly variable, we could make no meaningful statements about either general population levels of $^{137}Cs$ or the relative magnitude and/or rate of change within a single individual, because so many individual birds showed detectable body burdens on initial measurements, and showed none on recapture, or the reverse. The greatly improved sensitivity of the second counting system overcame this problem.

Demonstrating the utility of the improved whole body counter, Figure 7 illustrates the temporal variations in $^{137}Cs$ body burdens in a number of Blue Jays trapped repeatedly over extended intervals. As mentioned earlier, the unexplained disappearance of many Blue Jays during the winter of 1972 causes a gap in the data, but an examination of the figure will show that large changes have taken place in some individuals over relatively short periods. See, for example, bird number 101382588 which shows a radiocesium body-burden decrease of about a factor of six within 23 days, while bird number 101382595 demonstrates a similar drop, but adds a subsequent partial recovery.

The detection of $^{131}I$, detailed below, led to the suggestion that increased radiocesium levels might be expected to accompany any reactor-associated elevation of radioiodine levels. Sample groupings with

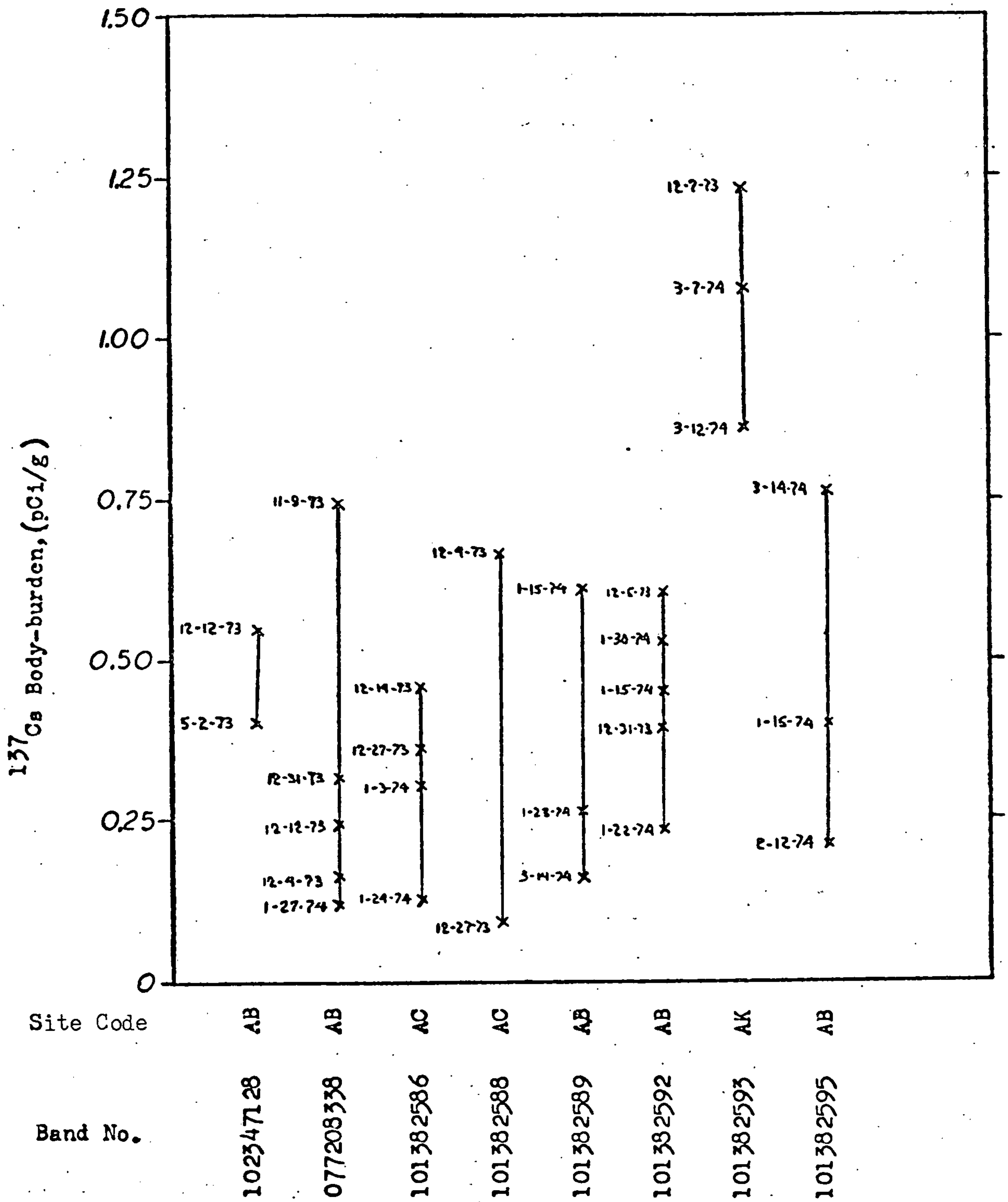



Figure 7. Temporal Variations of $^{137}$Cs Body Burdens in Blue Jays

respect to trapping sites were made for Blue Jays and Bobwhite and the body-burden statistics for each group calculated. Bobwhite taken from the sites on the nuclear power station property showed (a) that there is a difference in mean $^{137}Cs$ body burdens between the two trapping sites although the difference is not significant at the 2SD level; and (b) that Bobwhite taken from the Observatory site 3km SE of the reactor site show, in general, three to four times less radiocesium. Had we been limited only to birds from these three sites, we might have been led to suggest that some reactor-associated phenomenon was causing the elevated levels, for the three sites are quite similar in vegetation, meterology, and avian food sources. The $^{131}I$ data, cited below, would have served to materially reinforce such conclusions.

However, Bobwhite taken from the Buzzards Bay control site, 20km south of the power station, showed mean $^{137}Cs$ body burdens approximately three times greater than those of the reactor site birds. Examination of the Blue Jay data groupings demonstrated site-to-site differences, although the the two reactor site populations were indistinguishably similar. A summary of these data are presented in Table 4.

Table 4. Site-dependent Variations in $^{137}Cs$ Body Burdens.

| Species | Location | N | $^{137}Cs$ Mean ± S.D. (pCi/g) | $^{137}Cs$ Range (pCi/g) |
|---|---|---|---|---|
| Bobwhite | Control Site K | 17 | 0.68±0.44 | 0.03 - 1.97 |
| | Reactor Site C | 106 | 0.25±0.10 | 0.02 - 0.49 |
| | Reactor Site B | 86 | 0.17±0.11 | 0.00 - 0.49 |
| | MBO Site A | 10 | 0.01±0.03 | -0.03 - 0.07 |
| Blue Jay | Control Site K | 49 | 0.84±0.27 | 0.28 - 1.77 |
| | Reactor Site C | 93 | 0.48±0.35 | 0.05 - 1.41 |
| | Reactor Site B | 106 | 0.46±0.35 | 0.06 - 1.76 |
| | MBO Site A | 14 | 0.11±0.08 | -0.01 - 0.29 |

A study into the possible reasons for the variations in $^{137}Cs$ levels was begun. Soil and food samples were taken from each site for analysis. A large group of Red-winged Blackbirds and Mourning Doves which had just arrived on the Buzzards Bay site, the end point of their northward migration, was banded. It was planned to monitor these birds carefully throughout the duration of their stay on their summer territory. Although quite similar to the Bobwhite and the Blue Jay in their food habits, the Red-wings and Mourning Doves measured elsewhere by the project had shown very low levels of $^{137}Cs$, usually below detection limits. We hoped that following a newly-introduced population in an area which produced high radiocesium levels in other species (Bobwhite and Blue Jay) an insight might be gained into differential bioaccumulation mechanisms.

Another factor under consideration in the search for an explanation of the site-differentiated $^{137}Cs$ levels was the meteorological differences between the trapping sites. The influence on the local weather caused by the extreme water temperature differential between the two ends of the Cape Cod Canal, which is immediately adjacent to the Buzzards Bay control site, was investigated as a possible cause of thunder storms during the summer. Such storms, with their characteristically associated upper atmospheric turbulence might materially affect local fallout distribution. The location of the closed control site at Scusset beach would be similarly affected by the canal, and some consideration was given to a temporary reopening of the site in a parallel investigative effort.

6. Detection of $^{131}I$.

In early January of 1974, detectable levels of $^{131}I$ were found in Blue Jays and Quail taken from the trapping sites at the Pilgrim Nuclear Power Station. Radioiodine was detected in 40 of the 52 individuals trapped between 1/1/74 and 2/14/74. Thirty-six birds of the group which had detectable $^{131}I$ had levels $>$ 2.58 S.D. above background. The highest measured body burden was $0.24 \pm 0.06$ pCi/g. During the same period four Bobwhite Quail and two Blue Jays were trapped at the MBO site; none had detectable levels of $^{131}I$. Data from reactor site birds taken during the two months preceeding the initial appearance of $^{131}I$ (November and December of 1973) which included 19 quail and jays showed that only two Blue Jays showed any indications of $^{131}I$ activity as much as 1.96 SD

(95% confidence limit) above background. No birds in this group had iodine levels at or near the 2.58 SD (99% confidence limit) above background level.

There were three occasions on which the $^{131}I$ was detected. The first occurred on Monday, January 7, 1974. Subsequent inquiries indicated that the pressure vessel of the Pilgrim Station reactor was opened on Friday, January 4, 1974. During the period 1/4/74 to 1/8/74, fresh snowfall covered a good deal of the birds natural food supply. The second and third appearances of $^{131}I$ in reactor site birds (1/16/74-1/21/74 and 2/13/74-2/14/74) were associated with rising temperatures and melting snow cover indicating a possibility that the source of the radioiodine was in food stuffs made available to the birds only at these times. During this entire period the radiation monitors at the Pilgrim Station had shown no indications of unusual activity releases.

In addition to the identification of $^{131}I$ by its gamma-ray energy (0.364 MeV), we attempted to make a further confirmation by making decay measurements on a single sacrificed specimen. The observed value for the half life of 9.3±2.0 days is not inconsistent with the true $^{131}I$ value of 8.06 days, especially at these relatively low levels of activity.

A major complication in all of these iodine measurements is the apparent transit time of the activity through the avian gastrointestinal tract which has been determined by our measurements to be on the order of six hours or less. The fact that birds are normally caught in small groups coupled with the 100-min counts means that many birds are held in captivity for periods which are long with respect to this apparent transit time prior to being counted. Thus the measured activity might well have been a good deal lower in these late-measured birds than the true environmental levels. Attempts to measure $^{131}I$ in the excreta were unsuccessful, possibly due to the volatility of the iodine or its com pounds and/or inadequate methods of excrement collection in use at the time.

Measurements indicated that $^{131}I$ activity was not detectable in melted snow cover taken from the trapping sites nor was it found in either wipes of the outer feather surfaces of the birds nor in measurements of the feathers themselves taken from sacrificed birds, seemingly ruling out any cloud-immersion phenomenon. In one dissected specimen separate measurements were made of the whole bird, of the feathers, of the crop and its contents, the remaining gastrointestinal tract, the thyroid and surrounding tissues, and of the remaining carcass. The GI tract sample showed the bulk of the $^{131}I$ activity while none of the remaining individual samples showed iodine activity above system detection limits.

All of the evidence suggests that $^{131}I$ was detected in a number of birds resident on the reactor site coincident with the opening of the reactor pressure vessel for servicing and refuelling. The release of any activity in gaseous form due to the opening of the primary containment vessel would be expected to occur through the building vent system which exhausts at a point 46m above mean sea level (msl) rather than via the normal gaseous release pathway which is the main vent stack which releases at a point 122m above msl. The main vent stack is, of course, used for all releases during normal plant operation. The building release point, being about 75m lower than the stack release point, can be expected to produce very different diffusion patterns, especially taking into account the semi-bowl shaped nature of the reactor site. It appears that the activity detected in the birds was neither an external contamination nor an inhalation phenomenon, but was ingested activity. It also appears that the ingested activity passed through the gastrointestinal tract very rapidly as is the characteristic of all food material in small birds.

We considered the possibility that the detected activity might have been radium from gravel eaten by the bird. Some sand or gravel is ingested by all birds as an aid to the digestive process. Careful study of the bird spectra in comparison with radium spectra and comparative measurements of soil samples indicated that this possibility could safely be discarded, especially since no activity was detected in the crop or crop contents of the sacrificed bird. In addition, examination of the fecal matter and discussions with MBO biologists suggest little evidence of such a rapid turnover of gizzard gravel content.

C. July, 1974 to June, 1975

1. Summary

During this period the feasibility and practicality of using wild avian populations for detailed long-term environmental studies was clearly and conclusively demonstrated. Standard avian census techniques showed that a high percentage of the bird species present were actually captured for study, and recapture frequencies indicated that no significant alteration of the habits or survival probabilities of the captured birds was caused by our handling techniques.

With the new whole-body counter in full-time use the number of avian specimens measured more than tripled over the previous year. This significant increase was made possible in large part by the addition of a full-time laboratory assistant to the project staff making round-the-clock operation possible. Although the total number of new birds banded by the field staff was about the same as in the previous year, the percentage of repeat captures more than doubled.

The radionuclide measurements produced several interesting results. In addition to the continuation of the geographical variations in $^{137}Cs$ body burdens noted previously, we found evidence of a significant temporal change in average $^{137}Cs$ body-burdens occurring only at the reactor trapping sites. Radiocesium body burdens in a number of species decreased by as much as a factor of five in a uniform manner over a period of about two months.

A single catbird with an unusually high level of $^{95}Zr$-$^{95}Nb$ was trapped at the reactor site and held for repeated measurements over a fourteen-day period. The source of this radionuclide is unknown; there was

no evidence of a coincidental Chinese atmospheric nuclear test at that time to account for the $^{95}Zr$-$^{95}Nb$.

A program of interlaboratory comparisons was carried out to check the validity of our measurements. In one case, sophisticated least-squares analysis programs at the National Engineering Laboratory, Idaho Falls, Idaho, were used to analyze data generated at our laboratory; in the second test, totally independent measurements were made on collected avian specimens at both the Manomet Bird Observatory and at Battelle Northwest Laboratories, Richland, Washington. The results of these intercomparisons gave us a great deal of confidence in our measurements.

Initial steps toward the utilization of $^{40}K$ measurements in lean body mass studies were taken.

Finally, exploratory excercises in extending the sampling techniques developed in this program to sites far removed from our base laboratory were performed. The goal of these activities was to establish the practicalities and cost factors involved in a quick response capability for ecosystem radionuclide sampling using local avifauna.

2. Field Activities

During this reporting year 2720 new birds of 91 species were banded. An additional 1550 birds which had been banded previously were retrapped for an overall repeat percentage of 57%. As has been pointed out, the repeat percentage was expected to rise to some limiting value as a continually larger fraction of site residents was banded. With a minimum of eighteen months experience at each of the trapping sites, the repeat percentage has more than doubled (28% to 57%) although the total number of newly banded birds increased by only about 9% ( $\approx$ 2500 birds during the previous year vs. 2720 birds this year). At this point, the overall percentage of repeats was reaching what was considered a probable limiting value due to the wide diversity of species handled and to the low survival probability of first-year birds which represented a significant proportion of the newly-banded birds. Data to be presented below in the laboratory activities section demonstrates that for adult birds of some species, repeat rates of up to 80% were being achieved, indicating good population stability.

In order to determine the quality of our sampling techniques, a widely used method of bird censusing was employed at the trapping sites. Although it has been intuitively clear to the field personnel associated with the program that we were accessing a significant proportion of the total resident avifauna at the trapping sites, no quantitative determination had been attempted. The techniques used are described by a number of authors (Hickey, Pettingill, Wallace). The goal was simply to compare the number of species actually captured with the total number of species seen or heard singing at a given site. The nominal breeding season, i.e., June to mid-July, is considered to be the optimum time for surveys of this sort for three reasons. First, at this time, the production of food in the environment is at a maximum, as is the birds' use of the food, since most species are hatching young and thus exploiting more thoroughly the available resources. Secondly, censuses taken earlier or later might include numbers of migrant species or young birds which dispersed to the census area after hatching elsewhere. Finally, the various censusing techniques are most effective during this time period due to a significant dependence on nest location and/or song identification as input data.

The method used is generally referred to as a census-strip or transect count. Using the project's nominal 225-m net lanes as the center line through the plot to be censused, the site was subdivided into a series of strips parallel to the net lane. These strips were marked at 30-m intervals. The observer walked slowly along the strips in a grid pattern, down the first strip and in a reverse direction for the next, etc. At each 30-m marker, the observer stopped to listen for singing or calling birds and to note any birds or nests seen. Emlen (1971) discusses the relative effectiveness of these and other techniques with respect to determining population densities, pointing out drawbacks of each method. However, since our goal was not to determine population densities, but only to establish the presence of various species, most of the drawbacks noted do not apply.

Census strips were conducted three times at each of the four net sites during the mid-morning hours when feeding and singing activity of the residents was at a maximum. Evening census strips were run to establish the presence of nocturnal species such as the Whip-Poor-Will and Woodcock. Forty-five species were recorded during the census-strip activities. Of these, thirty-seven, or 82% were also trapped during normal trapping operations. While 82% appears to be evidence of a reasonably efficient sampling of the resident population, there are a number of factors that prevented us from achieving an even higher sampling percentage. First, most birds occupy territories the extent of which are roughly proportional to their body size (Schoener, 1968). We have usually stated this relationship in terms of population density for any species being approximately inversely proportional to body size. Thus for example Yellowthroat, Rufous-sided Towhee and Song Sparrow can be relatively numerous within a short distance of the net lane, and the chances of capturing these small birds are high. On the other hand, birds such as hawks, woodpeckers, and other larger birds defend territories of much greater areas and can thus be expected to occur much less frequently, even if a net lane runs through a considerable portion of that territory. Secondly, being a continuous, partially open swath through woodlands, the net lane creates an edge effect to some extent. This edge tends to act as a natural boundary between birds' territories which only rarely will be crossed during the breeding season. Thus it would not be unusual to see or hear some species on the parallel census strips but rarely catch them in the nets. Examples of such birds from the present census are Brown Thrasher, Carolina Wren and Ovenbird, commonly seen and/or heard, but rarely netted during the census period. A few other species apparently possessed territories which were tangential to or only narrowly intersected by the census strips and, though they were heard calling, they remained a considerable distance from the net lane. In this category are included Great Crested Flycatcher, Wood Pewee and Purple Finch.

Additionally, species such as the Ruffed Grouse, Bobwhite and Woodcock much prefer to walk rather than fly during their feeding routines and will thus pass under the nets. Ground traps are effective in sampling these species, but the area of coverage (or drawing area) of traps is far less than that of nets, and the effectiveness of baited traps seems inversely proportional to the availability of natural food supplies. Thus trap success was at a minimum during the period of the census.

A third group of species censused but trapped infrequently include birds feeding high in the forest canopy well above the 2.5-m maximum height of our mist nets. The Scarlet Tanager and the Red-eyed Vireo are included in this group.

Species that disperse widely to feed are yet another group detected by the census but infrequently netted in numbers proportional to the rate of recording by the census. These birds, including Mourning Dove, Common Crow, Red-winged Blackbird and Grackle, habitually fly up to several miles to forage so that during census-strips they would be seen or heard as they passes through or above the canopy. We should note, however, that we caught significant numbers of Mourning Doves, Redwings and Grackles in ground traps during much of their non-breeding time of residence at the trapping sites.

Finally, certain birds like the Cedar Waxwing and the American Goldfinch do not begin nesting until after mid-July so that their appearance at our net sites during the time of the census would tend to be sporadic.

In light of the factors cited above it seems clear that the netting and trapping techniques which enabled us to access 82% of the species censused are indeed an effective tool for sampling accurately the avifauna of a study area.

3. <u>Trapping Site Vegetation Survey</u>

A descriptive vegetation survey of the three primary trapping sites was conducted during this year. This work was intended to isolate and measure botanical variables which might have contributed to the radionuclide differences observed at the various trapping sites.

The vegetation of site AB, the western-most of the two reactor trap sites, consists of two distinct types, one passing rather abruptly into the other and sharing a number of species with it. The first consists of a young woodland some 10-12m tall situated on the landward portion of the site and, with reference to the net lane, extending out to about the fifth net (70m). The major component of this forest is Black Oak (Quercus velutina), far outnumbering all other species combined. Second in prominence is White Oak (Q. alba) with scattered individuals throughout. Of lesser importance, although reaching canopy height, are Scarlet Oak (Q. coccinea), Pitch Pine (Pinus rigida), and Mockernut Hickory (Carya tomentosa). Here and there are found Gray Birch (Betula populifolia) and along edges, Staghorn Sumac (Rhus typhina), both reaching sub-canopy height. Numerous standing and fallen dead trees no doubt succumbed in a great fire that swept the area in 1957. It is likely that the present thin-boled, short forest represents new growth following that fire.

Undergrowth here consiste primarily of Bullbrier (Smilax rotundifolia), Arrow-wood (Viburnum recognitum), Bayberry (Myrica pensylvanica), Morrow Honeysuckle (Lonicera morrowi), Sawbrier (Smilax glauca), and Summer Grape (Vitis aestivalis). Ground herbs are very few in number and scattered, except for White Wood-aster (Aster divaricata) which is common.

Toward the ocean the character of this forest changes quickly to that of a dense and impenetrable thicket some 2 - 3m high which continues unbroken and only slightly less in stature to the edge of the bluff. Major components of the thicket include the following in order of abundance: Arrow-wood, Bullbrier, Black Cherry (Prunus serotina), Staghorn Sumac, Common Highbush Blueberry (Vaccinium corymbosum), Black Oak, and a few adventive spruces (Picea). Ground herbs are more numerous but are more associated with the open net lane than with the thicket itself. None are of any particular consequence to the avifauna except Japanese Honeysuckle (Lonicera japonica) whose berries, along with those of the shrubs of the thicket, provide food for nesting and migrating birds into the late fall.

Site AC, just south of the power plant, presents a different aspect than that of site AB with respect to the canopy woodland. Flanking the first four nets is a 15-m tall woodland of Black Locust (Robina pseudoacacia) and Black Cherry, with Red Maple (Acer rubrum) dominating around two wet shallow swales. This forest merges rapidly into a Black Oak - Black Cherry - White Oak forest of similar height, again with Red Maple locally dominant. A number of Red Cedar (Juniperus virginianum), Gray Birch, oaks and cherry form a sub-canopy.

Under the locusts, the shrub layer is very dense with Morrow Honeysuckle, Blackberry (Rubus sp.), Bullbrier and Japanese Honeysuckle; whereas under the oak/cherry section it is composed of Bullbrier, cherry saplings, Arrow-wood, American Hazlenut (Corylus americana) Sawbrier, Morrow Honeysuckle and, in the wet swales, Swamp Azalea ( Rhododendron viscosum). Ground covers are few and insignificant.

This forest gradually diminishes in stature so that by the tenth net (travelling seaward), one is again presented with an impenetrable thicket composed of the following: Arrow-wood, Bullbrier, Black Cherry, Black Oak, Gray Birch, Bayberry, Common Highbush Blueberry, Sawbrier, Scrub Oak (Q. ilicifolia), White Oak, Thicket Shadbush (Amelanchier canadensis), and Sweet Pepperbush (Clethra alnifolia).

Control site AK is situated at the northeast edge of an artificially enlarged pond. It is bounded on the pond side by a strip of forest, and to the north by a disused, overgrown commercial cranberry bog. Like most old bogs, this one has a limited supply of water that flows through it to the pond, the bog being wet usually through mid-July, but becoming rather dry by the end of August. Since the abandonment of the bog in 1965, it has grown up to a dense stand of Dusky Bullrush (Scirpus atrovirens) and Canada Rush (Juncus canadensis), with

Sphagnum Moss (*Sphagnum* sp.), Leatherleaf (*Cassandra calyculata*), and Inkberry Holly (*Ilex glabra*) as lesser associates.

The narrow strip of forest between the net lane and the pond is composed of Pitch Pine, Black Oak, White Oak, Red Maple, with a scattering of Bigtooth Aspen (*Populus grandidentata*). It is generally 9-11m tall, open in aspect, and represents a typical development of a pine-barren forest in proximity to a pond.

Undergrowth consists of shrubs of various heights, especially Black Huckleberry (*Gaylussacia baccata*), Scrub Oak and Bayberry. Toward the water, a dense wall of taller shrubs takes over, including Inkberry Holly, Arrow-wood and Black Highbush Blueberry (*Vaccinium atrococcum*). Common ground covers of value to wildlife are Wintergreen (*Gaultheria procumbens*) and Early Low Blueberry (*Vaccinium vacillans*).

4. Additional Control Site Opened

With the continuation of the geographic variations in $^{137}Cs$ reported earlier, and the reactor-site $^{137}Cs$ body-burden decreases described below, we felt it desirable to establish an additional control site. A useable site located half-way between the reactor and the primary control site was set up. Its location is illustrated in Figure 8. Although the vegetation at this site is quite different from the other trapping sires, its physical location together with the fact that it has been censused accurately over a number of years make it ideal for our purposes. Although limited to four nets at this site, the relatively dense avian population found there as well as its designation as a secondary site made this limitation acceptable.

5. Laboratory Operations

The addition of a full-time laboratory assistant and the now-routine operation of the second whole-body counting system allowed us to more than triple the sample throughput of the radionuclide measurement laboratory during this year. Two-thousand-forty-seven birds were counted

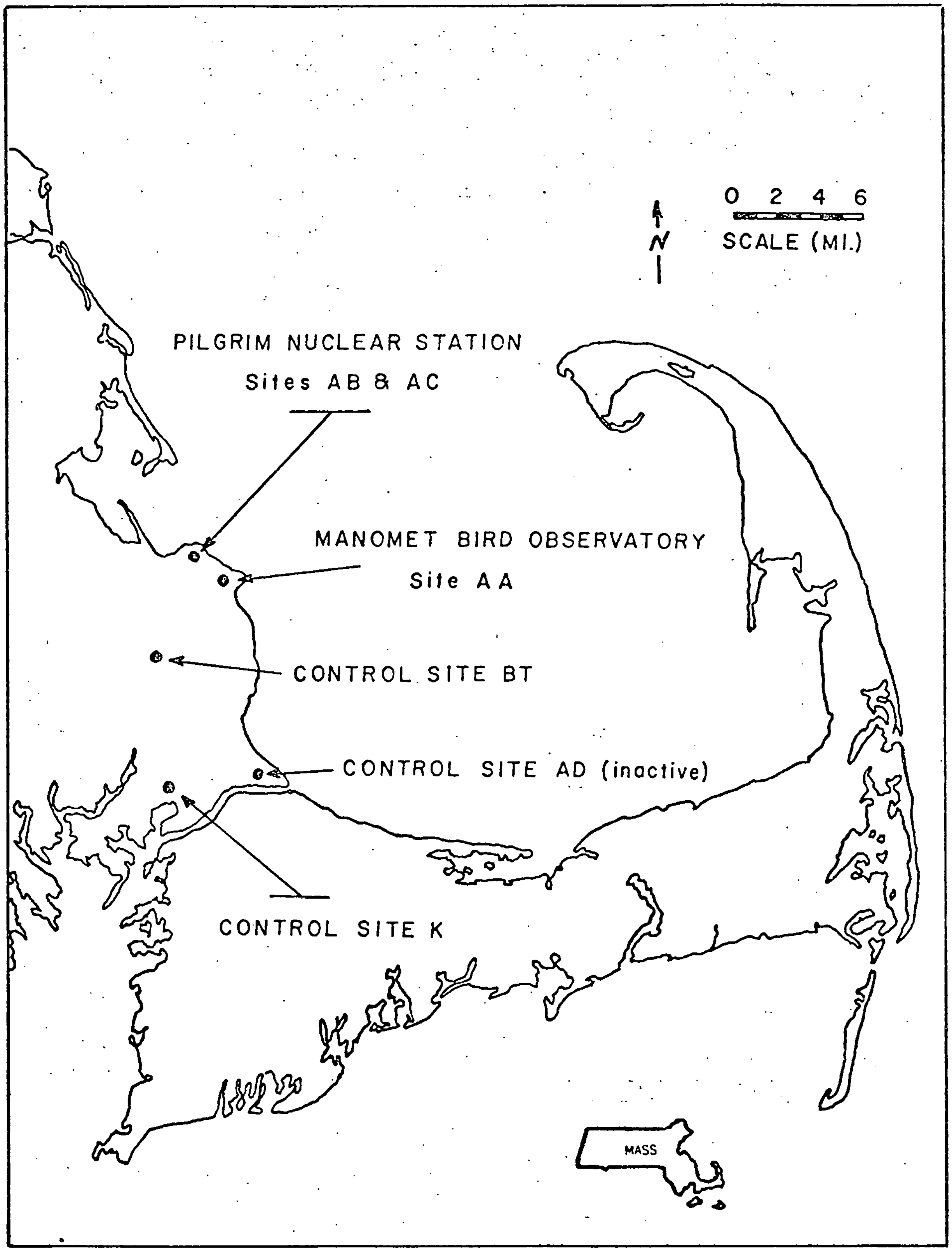



Figure 8. Location of Additional Control Site.

as a part of the routine measurement program. Biological half-life measurements, mammal work, and the measurements of backgrounds and calibrations added to the overall workload producing an average daily (24 hour) utilization rate for the radionuclide measurement laboratory of about 80%. Forty species of birds were measured; the overall repeat rate for radionuclide measurements was 28%. For a number of frequently handled species, the repeat rates were much higher. Bobwhite from the reactor station sites had a 74% repeat rate, while every third Blue Jay from all sites had been measured one or more times previously.

A modular electronics system (NIM modules) enabled us to reactivate the first whole-body counting chamber (the electronics associated originally with the first system were now in use with the new counter). It proved to be of great value in making repetitive measurements on dead specimens, either in their entirety or as component parts analyzed with the well counter. Three channels of electronics were acquired so that three different nuclides or energy regions could be studied simultaneously. As was pointed out previously, one of the two crystals in the first counter was a well-type crystal, and the new electronics, used in conjunction with this well counter allowed high-sensitivity measurements of small organs or tissue samples.

The original counter was recalibrated with its new electronics. The primary use of this system has been for the measurement of $^{137}Cs$ and $^{40}K$ in dead specimens, including mammals. In order to determine the effects, if any, of different sample volumes on the detection limits of the well counter, seven identical $^{137}Cs$ sources were made up. These liquid sources were then diluted in agar to make sample volumes of 1 to 7cc in one-cc steps. These samples were then sealed in vials like those used for our sample counting. Using these sources we were able to determine that sample volumes of 3 - 6cc may be counted with a volume-attributed error of less than ±2%.

## 6. Inter-laboratory Comparisons

In order to ascertain the adequacy of our measurement techniques both with respect to the calcualtions and to the methods by which our spectra are analyzed, we conducted two interlaboratory comparisons.

Our method of calculating net radionuclide activities involves summing over energy bands corresponding to the photopeaks of the appropriate gamma rays. For each energy band, necessary corrections are made for the Compton scatter of gamma rays of higher energy than the energy band of interest. In addition, backgrounds are taken at two times during the day; at these extremely low levels it is quite possible that the background for a particular measurement, especially in the periods considerably removed in time from the time of recording the background, might not be as appropriate as a background taken immediately before or after the specimen measurement.

Little subtleties like this at these very low counting rates might seriously affect our results without our knowing so, and might incorporate systematic errors about which we would be totally unaware. These subtleties could also affect our minimum detection limits. To check on this, we had some of our data analyzed by linear least-squares techniques in a collaborative effort with Russell L. Heath at the Idaho National Engineering Laboratory (INEL) at Idaho Falls, Idaho. Various spectra of typical bird measurements, the appropriate backgrounds, and phantom calibration results for various isotopes were taken to Idaho and analyzed using the interactive computer programs that Heath and his associates Richard G. Helmer and William R. Meyers have developed over the years. As a result of the first trials, it was concluded that it would be appropriate to have a mixed phantom of three nuclides, namely, $^{40}K$, $^{137}Cs$ and $^{131}I$, in order better to assess the sensitivity for $^{131}I$ in the presence of these other two nuclides which had been normally and typically found in bird spectra. Our interest in $^{131}I$ was primarily due to the fact that it was the only radionuclide which we had detected in birds which had a high probability of being directly attributable to the reactor, as has been described previously. The results of the comparison between our calculations and the Idaho calculations are as follows:

| Nuclide | Samples Analyzed | Ratio MBO/INEL ($\bar{x} \pm S.D._{\bar{x}}$) |
|---|---|---|
| $^{131}I$ | 6 | 2.24 ± 0.45 |
| $^{137}Cs$ | 14 | 1.05 ± 0.04 |
| $^{40}K$ (INEL whole spectrum) | 13 | 1.72 ± 0.12 |
| $^{40}K$ (INEL peak) | 12 | 1.10 ± 0.12 |

Dropouts in the MBO spectrum tapes caused the sample number differences between the $^{137}Cs$ and $^{40}K$ sample totals.

The results for $^{137}Cs$ were quite satisfactory. The results for $^{131}I$ indicate that we might have been systematically greater than INEL by a factor of two. On the other hand, the errors associated with the MBO values were two times greater than those of INEL (1.97 ± 0.14). Therefore, the ability to detect activity is the same from both calculations, although our calculations led to a larger value. In the results tabulated above, four of the samples showed detectable activity in both calculations, a fifth showed detectable activity only in the MBO calculations, and a sixth showed activity only in the INEL data reduction. This is a difficult inter-comparison at levels which are just detectable. It would appear that when net $^{131}I$ activity is detected by these calculations, there is reasonable assurance that the results are to be trusted.

The results for $^{40}K$ were somewhat different than those from the other two nuclides, and may point out some subtle effects. It will be noted that the $^{40}K$ results by our calculations were systematically greater than those of INEL by a factor of 1.7 when the INEL calculation was made using the whole spectrum. On the other hand, if the Idaho calculations were made again by the least-squares technique, but including only the $^{40}K$ peak, then the results from the two calculations were essentially identical. Whether or not this discrepancy is due to the phantoms that we used not being exact replicas of real birds (since we had no skeletal material in them), or to a difference in the background during the bird count and the background actually used for data reduction is not known.

The second inter-comparison was made at Battelle Northwest Laboratories, Richland, Washington, in cooperation with Richard L. Perkins and Ned A. Wogman. In this inter-comparison we measured five frozen birds sealed in polyethylene bags, packed them in dry ice, and shipped them to Battelle Northwest for independent radionuclide measurements. The Battelle measurements were carried out on the intact frozen birds using multi-dimensional analysis detectors and anti-coincidence-shielded Ge(Li) detectors. Battelle used their own radionuclide standards consisting of radioactivity distributed in an aluminum oxide matrix contained in a pill-box shaped aluminum can matching the geometry that was required for the birds. The exact geometry of the bird and the standards was therefore not identical, but both were contained in the same corresponding sized cans.

Since the sensitivity of the MBO instrumentation is less than that of the Battelle laboratory, not all birds could be compared for the three nuclides, since in half the instances, we at MBO could not detect them. The results, given as the ratio r = MBO/BNWL, were as follows: (a) $^{40}K$, r = 1.26 (n = 4, range 0.79 - 1.66); (b) $^{137}Cs$, r = 0.91 (2, 0.81 - 1.01); (c) $^{95}Zr$-$^{95}Nb$, r = 0.96 (1). On the whole, the two inter-laboratory comparisons were reasonably satisfactory for $^{137}Cs$ and for $^{40}K$ and further substantiate the fact that we had no major systematic errors in the body-burden data which had been gathered.

The greater sensitivity of the BNWL detectors allowed the detection of $^{7}Be$, $^{22}Na$, and $^{144}Ce$ in our birds in addition to the nuclides enumerated above.

The birds sent to BNWL contained no detectable $^{131}I$ at the time they were collected; no independent check on this nuclide could be made.

## 7. Meteorological Data

We previously suggested that the regional variations in the $^{137}Cs$ body burdens might be influenced by microclimatological conditions; the AEC DBER concurred and proposed that we consider availing ourselves of the services of a meteorological consultant in order to help explain some of the possible causes of local radiocesium variations.

We were fortunate to be able to obtain the assistance of Dr. H. Houghton, Emeritus Professor and former head of the Department of Meteorology at MIT. Professor Houghton indicated that significant amounts of $^{137}Cs$ are deposited through rainout and washout mechanisms, and that were precipitation differences greater than about 15% between different sites, rainfall might be a significant factor; if differences approached 50%, rainfall would be a very significant factor. Differences of < 10 - 15% would probably rule out precipitation as a major factor in the site differences. Dry deposition of fallout also occurs, although Professor Houghton felt that it was less significant than rainfall-associated effects. The diversity and density of the vegetation intercepting the fallout prior to its reaching the ground affect the $^{137}Cs$ availability at any given site. A third factor to be considered is the rate of ocean-induced salt deposition which can vary by as much as a factor of thirty from the ocean-vegetation boundary to just a few miles inland. Examination of the site location maps suggest that the MBO site (AA) receives a higher degree of salt deposition while control site AK receives the lesser, with the reactor trapping sites receiving an intermediate amount. It is expected that, should salt spray be a significant factor at any location, the $^{137}Cs$ availability would be inversely proportional to salt concentration.

In accordance with Professor Houghton's suggestions, we collected available climatological data. Comprehensive wind distribution data were taken from the environmental impact publications of the Pilgrim Nuclear Power Station (our primary study site) and from the New Bedford Gas and Electric Company's Cape Cod Canal Generating Station which is adjacent to the now-closed original control site, and 6.5km east of control site K. Rainfall and temperature data were obtained from the New England River Basins Commission for stations within 5km of the reactor and control sites. Examination of these data indicated that (a) seasonal and annual temperature differences were $< \pm 2.5\%$, (b) seasonal and annual precipitation differences were $< \pm 9\%$, and (c) there were no significant differences in wind distributions. In addition, it is the opinion of the botanist who performed the site vegetation survey presented above that no evident salt-spray differentiation effects exist at the trapping sites. Accordingly, there appeared to be little evidence that climatic effects were playing a significant role in the site-differentiated $^{137}Cs$ body-burden data.

8. Soil Chemistry

Previous research has indicated that soil chemistry may play a major part in determining nuclide availability, and that soil chemistry may be highly variable over limited areas. As a preliminary evaluation of the potential importance of these factors especially with respect to the site-dependent $^{137}Cs$ variations, a single soil and vegetation sample was taken from grassy areas at each of the four sites from which we had obtained bird specimens. The new control site (BT) had not been opened at the time of this survey. Each sample was a multi-part specimen consisting of (a) surface grasses and associated small vegetation, (b) the first 2.5-cm layer of soil, (c) the plant root material from sample (b), and (d) the second 2.5-cm soil layer. These samples were measured in the whole-body counter with the following results:

| Sample | Site | Wt. (g) | $^{137}Cs$ (pCi/g) | K g(K)/kg |
|---|---|---|---|---|
| Grass | AA | 200 | 2.01±0.04 | 5.94±0.26 |
| | AB | 173 | 1.82±0.04 | 9.42±0.30 |
| | AC | 200 | 3.69±0.04 | 7.72±0.26 |
| | AK | 115 | 0.87±0.06 | 5.92±0.46 |

Results, Soil Radionuclide Measurements, continued

| Sample | Site | Wt. (g) | $^{137}Cs$ (pCi/g) | K g(K)/kg |
|---|---|---|---|---|
| Top 2.5cm soil | AA | 500 | 0.49±0.02 | 8.13±0.12 |
| | AB | 500 | 1.93±0.02 | 12.39±0.12 |
| | AC | 500 | 1.02±0.02 | 10.02±0.12 |
| | AK | 385 | 0.87±0.02 | 6.18±0.15 |
| Roots | AA | 3.1 | -0.23±2.36 | -1.75±17.05 |
| | AB | 20.5 | 0.91±0.36 | 0.39±2.58 |
| | AC | 7.9 | 0.77±0.93 | -1.54±6.69 |
| | AK | 30.5 | 0.00±0.24 | 3.19±1.73 |
| Second 2.5cm soil | AA | 500 | 1.54±0.02 | 6.95±0.11 |
| | AB | 500 | 0.65±0.02 | 7.56±0.11 |
| | AC | 500 | 0.38±0.02 | 11.51±0.11 |
| | AK | 500 | 0.97±0.02 | 7.27±0.11 |

The conclusions from this preliminary survey were that there is no relationship between the observed $^{137}Cs$ body burdens in site-resident avifauna and the soil $^{137}Cs$ levels, nor is there an apparent relationship between soil $^{137}Cs$ and soil potassium levels. It is evident that with the probable elimination of weather differences and soil radionuclide levels as causative or contributory factors to the observed radionuclide differences, the $^{137}Cs$ site-dependent variations remain unexplained.

9. Summary Results, Radionuclide Levels

Measurements of radionuclide body burdens made on 15 representative species (1346 individuals captured between 9/73 and 2/75) from all trapping sites are summarized in Table 5. Of these birds, about 40% have been counted two or more times, although each bird is entered into the tabular statistics only once. Of the isotopes listed in the table, $^{131}I$ was observed only once during a two-month period as has been previously noted. Transient appearances of $^{95}Zr$-$^{95}Nb$ have generally followed announced Chinese atmospheric nuclear weapons tests. The average potassium concentration for all tabulated species except the Black Duck and the Ruffed Grouse is 2.56 ± 0.43g/kg body mass. The potassium

| Species | N | Mean Weight g. | $^{131}I$ Mean ± S.D. (range) pCi/g | $^{137}Cs$ Mean ± S.D. (range) pCi/g | $^{95}Zr$-$^{95}Nb$ Mean ± S.D. (range) pCi/g | K Mean ± S.D. (range) g./Kg |
|---|---|---|---|---|---|---|
| Song Sparrow (*Melospiza melodia*) | 12 | 23 | -0.18±0.25 (-0.63)-(0.27) | -0.09±0.28 (-0.55)-(0.20) | -0.06±0.14 (-0.28)-(0.16) | 2.36±4.14 (-4.43)-10.17) |
| White-throated Sparrow (*Zonotrichia albicollis*) | 46 | 27 | -0.09±0.20 (-0.52)-(0.40) | -0.11±0.28 (-0.96-(0.47) | -0.04±0.14 (-0.46)-(0.41) | 1.64±2.76 (-6.13)-(10.17) |
| Grey Catbird (*Dumetella carolinensis*) | 258 | 38 | -0.03±0.18 (-0.01)-(0.70) | 0.02±0.24 (-0.01)-(1.13) | 0.02±0.22 (-0.01)-(1.08) | 2.11±1.95 (-3.56)-(7.25) |
| Rufous-sided Towhee (*Pipilo erythrophthalmus*) | 41 | 40 | -0.02±0.18 (-0.50)-(0.38) | 0.32±0.43 (-0.15)-(2.24) | 0.01±0.13 (-0.22)-(0.25) | 2.68±2.27 (-1.90)-(10.54) |
| Wood Thrush (*Hylocichla mustelina*) | 29 | 45 | 0.01±0.12 (-0.30)-(0.29) | 0.03±0.17 (-0.14)-(0.37) | -0.01±0.08 (-0.15)-(0.12) | 2.37±2.12 (-1.02)-(4.75) |
| Red-winged Blackbird (*Agelaius phoeniceus*) | 42 | 60 | 0.00±0.11 (-0.18)-(0.32) | -0.04±0.08 (-0.28)-(0.11) | 0.02±0.07 (-0.16)-(0.13) | 3.00±1.10 (1.01)-(5.95) |
| Brown Thrasher (*Toxostoma rufum*) | 41 | 71 | 0.01±0.08 (-0.15)-(0.13) | 0.10±0.15 (-0.15)-(0.49) | 0.03±0.08 (-0.19)-(0.16) | 2.15±1.11 (-0.61)-(5.08) |
| American Robin (*Turdus migratorius*) | 29 | 77 | 0.05±0.07 (-0.15)-(0.16) | 0.16±0.30 (-0.17)-(1.05) | 0.02±0.07 (-0.09)-(0.14) | 2.97±0.92 (1.26)-(4.37) |

Table 5. Summary of Body-burden Data in Selected Species.

| | | | | | | |
|---|---|---|---|---|---|---|
| Blue Jay (*Cyanocitta cristata*) | 384 | 93 | 0.04±0.08 (-0.18)-(0.24) | 0.76±0.52 (0.05)-(1.77) | 0.05±0.07 (-0.21)-(0.16) | 2.61±0.91 (0.92)-(4.91) |
| Common Grackle (*Quiscalus quiscula*) | 22 | 101 | 0.03±0.07 (-0.07)-(0.26) | 0.20±0.41 (-0.06)-(1.66) | 0.05±0.04 (-0.02)-(0.14) | 2.60±0.86 (1.29)-(4.25) |
| Yellow-shafted Flicker (*Colaptes auratus*) | 14 | 130 | 0.03±0.02 (-0.02)-(0.07) | 0.13±0.07 (0.03)-(0.26) | 0.03±0.03 (0.00)-(0.08) | 2.41±0.58 (1.46)-(3.22) |
| Mourning Dove (*Zenaida macroura*) | 25 | 132 | 0.03±0.05 (-0.03)-(0.05) | 0.00±0.06 (-0.10)-(0.17) | 0.02±0.04 (-0.09)-(0.09) | 2.40±1.24 (-0.46)-(4.57 |
| Bobwhite (*Colinus virginianus*) | 326 | 197 | 0.04±0.04 (-0.05)-(0.16) | 0.26±0.25 (0.00)-(1.97) | 0.05±0.03 (-0.04)-(0.11) | 2.63±0.59 (1.40)-(3.55) |
| Ruffed Grouse (*Bonasa umbellus*) | 38 | 552 | 0.06±0.03 (0.00)-(0.12) | 0.34±0.22 (0.01)-(0.82) | 0.04±0.03 (0.01)-(0.19) | 1.51±0.76 (0.83)-(3.43) |
| Black Duck (*Anas rubripes*) | 39 | 1157 | 0.00±0.02 (-0.03)-(0.04) | 0.04±0.14 (0.00)-(0.56) | -0.02±0.04 (-0.05)-(0.06) | 1.66±0.29 (1.10)-(4.41) |

(Table 5. - continuation)

content of human beings ranges from 1.5-2.0g/kg. The consistently higher avian values, though not statistically significant, may be accounted for by the larger mass ratio of muscle to skeleton in the bird as compared to human beings due to the lighter avian skeletal structure evolved for flight. The relatively lower potassium concentration found in the Black Duck is understandable in that local ducks in winter, when this population was accessed, are known to have extremely high levels of fat (Harrington & Lloyd-Evans, 1975). The comparably low levels of potassium in the Ruffed Grouse are unexplained. Measurements of whole sacrificed avian specimens of many different species, including the Ruffed Grouse, and of the separated body components of these birds have shown that < 2% of the detected potassium concentration is in or on the feathers.

## 10. $^{137}$Cs Measurements

Figures 8 and 9 present a representative sampling of $^{137}$Cs body-burden data for Bobwhite and Blue Jays taken over a sixteen month period. For Blue Jays, the two reactor trapping sites are illustrated separately; the separation between these two sites is greater than the nominal territory size of the adult Blue Jay and we were thus dealing with two distinct populations. The Bobwhite, however, move within an area large enough to encompass both trapping sites and, in fact, the same birds are often caught twice weekly, once at each site. The Bobwhite data from the two reactor trapping sites are therefore combined in this presentation. The figures clearly illustrate relatively rapid changes in individual body burdens. These changes are well outside the statistical error of measurement and therefore represent real changes attributable to environmental and/or physiological factors.

Since the temporal changes in the $^{137}$Cs body burdens are so large and occur so rapidly, the interpretation of burdens observed in a random group of birds, even of a single species, can be difficult. Furthermore, the body-burden distribution in groups of birds is so broad that only large changes from the average can be detected in a second

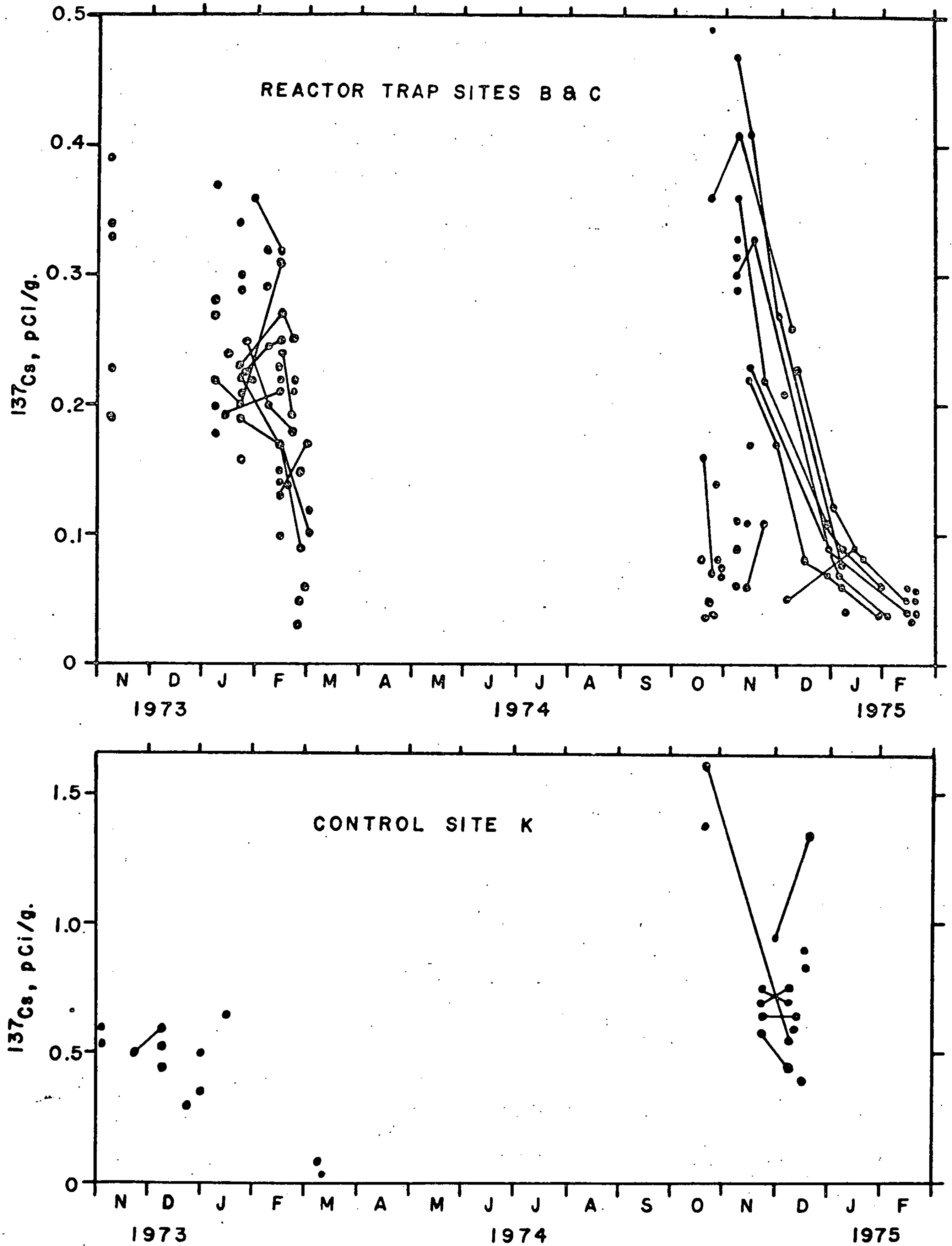



Figure 8. $^{137}$Cs Body burdens in representative Bobwhites from 11/73 to 2/75. The dots represent individual birds measured only once. Repetitive measurements of individual birds are shown with connecting lines. Bobwhites are less capturable during April to September due to breeding season dispersal and increased availability of natural food.

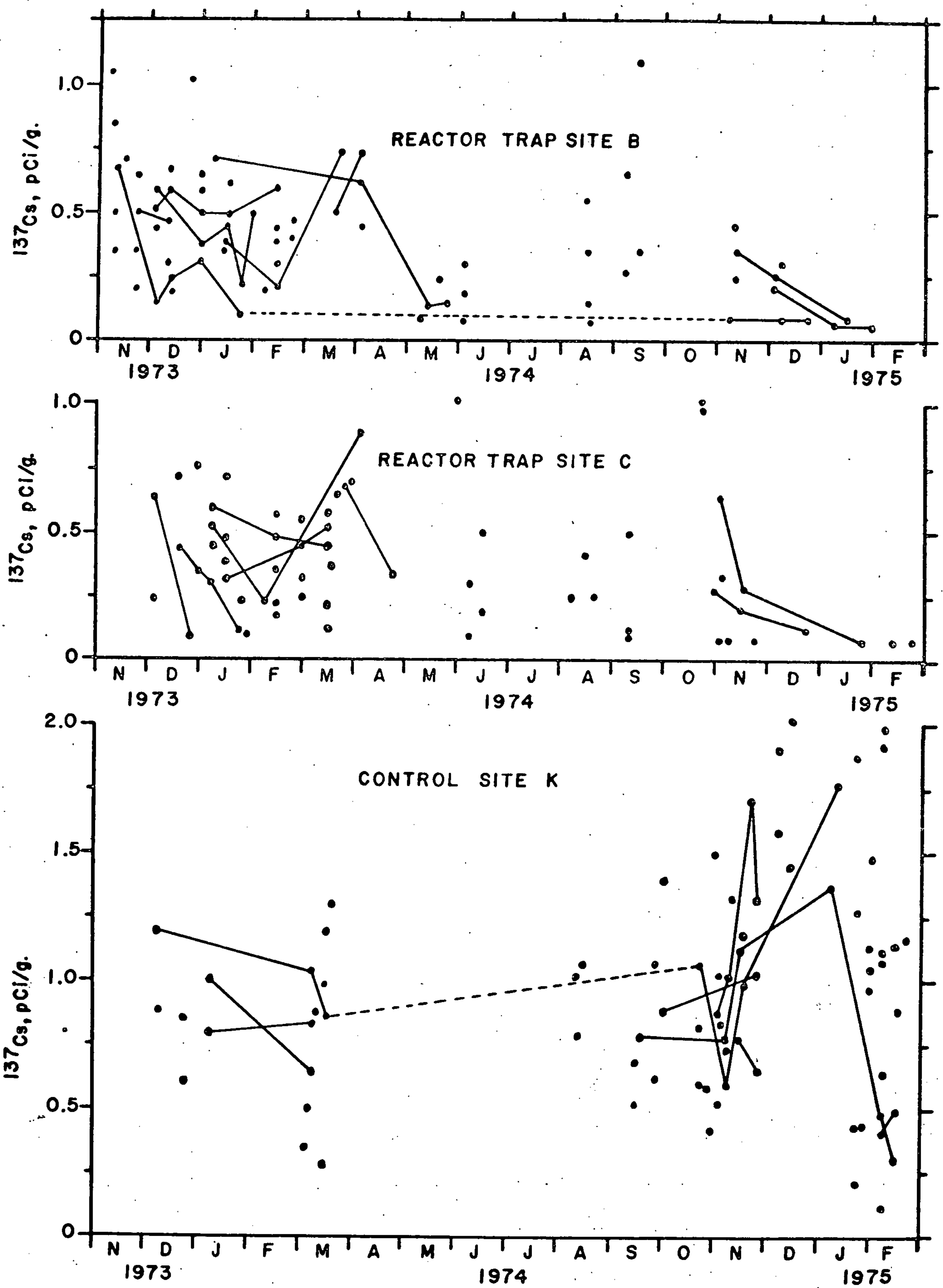



Figure 9. $^{137}Cs$ body burdens in representative Blue Jays from 11/73 to 2/75. The dots represent individual birds measured only once. Repetitive measurements of individual birds are shown with connecting lines. Blue Jays are less capturable from April to September due to breeding season dispersal and increased availability of natural food.

random sample. The utility of repeat measurements on recaptured birds is thus evident.

The site-dependent variations in $^{137}Cs$ body burdens remained essentially the same as indicated in Table 4 which presented data for the year 1973 - 1974. These data were combined with the Blue Jay and Bobwhite radiocesium data for 1974 - 1975 and subjected to a one-way analysis of variance to determine the significance of the site variations. Control site K continued to produce the highest average $^{137}Cs$ burdens, while preliminary indications from site BT (the new secondary control site) indicated that similar levels were to be found there. The BT sample size was not sufficiently large at the time of the statistical calculations to be included in the analysis.

For both Blue Jays and Bobwhites, the $^{137}Cs$ body burdens were significantly different ($p < 0.001$) between the MBO site, the reactor sites (treated as one), and control site K. Using an SNK (Student-Newman-Keuls) test for multiple comparisons among means based on unequal sample sizes (Sokal & Rohlf, 1969), the Blue Jays at the two reactor sites were not significantly differentiated with respect to $^{137}Cs$ body burdens at the $p = 0.01$ level. The reactor site Bobwhite populations were, however, differentiable between the two sites at the 0.01 level. This differentiation of the Bobwhites was unexpected. As was mentioned above, it is common to trap the same individuals at both trapping sites; catching the same Blue Jay at two different sites is rare. It would thus appear that those Bobwhite which are unique to each of the trapping sites, i.e., never moving to the other site, were sufficiently different in $^{137}Cs$ body burdens so as to alter the composite site $^{137}Cs$ data enough to produce this differentiation.

Except for the non-significance of the differentiation of Blue Jays between the two reactor trapping sites, all other intersite comparisons for both species were significantly different at the 0.01 level as determined by the SNK test. A summary of the ANOVA results (one way analysis of variance) for the site-dependent $^{137}Cs$ body burden data follows.

Summary of ANOVA Results for $^{137}Cs$ Body Burden Data

| Species | Site _ | vs. Site _ | Date | p | F | df |
|---|---|---|---|---|---|---|
| Bobwhite | At All Sites | | through 11/74 | <0.001 | 33.24 | 3, 220 |
| | At All Sites* | | after 11/74 | <0.001 | 156.66 | 2, 102 |
| | AB&AC | AK | 11/73 - 3/74 | <0.001 | 37.83 | 1, 78 |
| | AB&AC | AK | 10/74 - 2/75 | <0.001 | 218.75 | 1, 107 |
| Blue Jay | AB&AC | AK | 11/73 - 3/74 | <0.001 | 14.93 | 1, 88 |
| | AB&AC | AK | 4/74 - 9/74 | <0.025 | 6.76 | 1, 45 |
| | AB&AC | AK | 10/74 - 2/75 | <0.001 | 53.86 | 1, 72 |

11. $^{137}Cs$ Biological Half-life Measurements

In order to hold wild birds for the extended time periods necessary for the measurement of radionuclide biological half-lives, a number of stainless-steel cages were obtained. These cages, originally intended for medium-sized laboratory mammals, have interior dimensions of 30-cm high by 36-cm wide by 60-cm deep. They are well suited to house the birds with which we typically dealt. A Plexiglas sheet (0.6-cm thick) was added to cover the normal steel-bar grid floor on which the birds demonstrated some difficulty walking. A single perch was attached to the cage side. This combination of a single perch and the Plexiglas floor seemed to provide the best practical solution to the difficult problem of collecting the droppings of caged birds, although subsequent improvements were made during the externally administered metabolic studies, described later. The passerine species were found to spend much of their time on the perch, and the majority of the droppings were deposited under the perch. By placing the perch at a height above the floor such that the bird could not pass under it, we minimized the probability of the bird walking in its own droppings. Of course, some droppings were found in other parts of the cage and there was some pick-up of these on the bird's feet as it moves about the cage, but the quantity of these scattered droppings was small. The impervious surface of the Plexiglas floor allowed the thorough collection of all droppings.

The originally supplied mammal feeding boxes proved suitable for avian use, but water cups had to be provided as animal watering bottles were found totally unsuitable for use with birds. Flourescent light was used to approximate the outside ambient photoperiod and cage-room temperatures were maintained at about the outside ambient average.

Food supplied to the caged birds was radioassayed in lot sizes selected to maximize the counter sensitivity, i.e., the largest mass of food which could be counted at the optimum geometry. These measurements indicated that the food used had typical activity levels of $\leq$ 6fCi/g for all of the radionuclides for which the whole-body counters were calibrated. Thus even in the unlikely event of a bird consuming 50g of food, corresponding to somewhat more than $\frac{1}{2}$ the average Blue Jay weight, the $^{137}Cs$ input would be less than 0.15pCi total, or $<$ 18fCi/g (bird), a factor of 50 below the detection limits.

All birds used in this initial prototypical biological half-life determination were trapped at control site K. At the time, reactor site birds were of no use due to the sudden decrease in $^{137}Cs$ body burdens reported below. In order not to interfere with the routine avian measurement program a maximum of six birds was held at any one time for long-term half-life measurements. A single measurement cycle for a six-bird group required about twelve hours, so any larger group would have meant significant disruptions of the field measurement program. Birds were remeasured every two-to-four days; the remeasurement period was to some extent determined by weight loss and by the amount of observed physical activity while caged. Some birds simply did not adjust to being caged, continuing to fly against the cage top and sides, trying to escape. Captive birds were released either as their nuclide body burden reached system detection limits, or when severe and continuing weight loss indicated a complete failure to adapt to captivity. The release criterion for weight loss was set at a loss of $>$ 33% of the capture weight.

Measurements on the field-acquired (as opposed to laboratory-administered) $^{137}Cs$ body burdens of 11 Blue Jays held for periods as long 26 days indicated a biological half-life of 6.7 ± 1.5 days with a range of 3.2 - 9.1 days. This corresponds to an average daily excretion rate of ≈ 11%. The average biological half-life ($BT_{\frac{1}{2}}$) values found in this preliminary study were essentially the same as those found in the Wood Duck (Aix sponsa), 5.4 days with a range of 3.1 to 8.1 days. (Brisbin, 1975). However, the relationship of body weight to $^{137}Cs$ $BT_{\frac{1}{2}}$ established by the same researcher ($BT_{\frac{1}{2}} = -0.31 + 0.013w$, where w = weight in grams) is clearly inapplicable to the Blue Jay, the average weight of which is about 85g. Applying the Bribsin relationship to the Blue Jay predicted a $BT_{\frac{1}{2}}$ of less than one day.

Reichle in presenting data on the relationship of body weight to $^{137}Cs$ $BT_{\frac{1}{2}}$ in warm-blooded vertebrates presents equations which predict a value of 8.64 days for an 85g animal, a value in excellent agreement with our findings (Reichle, 1970).

The wide weight range of small, i.e., <250g, birds and the rapidity with which a bird's weight may vary under various environmental stresses suggested that the analysis of $BT_{\frac{1}{2}}$ with respect to weight would probably be unproductive. A small bird may lose more than 30% of its weight during a single very cold night, and subsequently completely regain this weight through intensive feeding the following day. When the presently unknown effects of capture stress are added to this potential 30% weight fluctuation, any attempt to use body weight as a covariant in $BT_{\frac{1}{2}}$ studies would seem unsupportable.

The eleven birds used for this study were held up to 26 days after which they were released at the site of their capture. A number of these birds were subsequently recaptured. On remeasurement, the $^{137}Cs$ body burdens as compared with the pre-release values indicated a reaccumulation rate of 16 ± 5% per day, a value not inconsistent with the excretion rates determined earlier.

These recaptures were important not only for the determination of re-accumulation rates, but also in that they demonstrated that it is possible to make these relatively long-term measurements on caged wild birds without significantly affecting their survival probabilities as members of a wild population, and that they can be reacquired after release to the wild.

## 12. Changes in $^{137}Cs$ Distributions

The distributions of $^{137}Cs$ body burdens in Blue Jays and Bobwhite over a sixteen-month period are shown in Figures 10 and 11. Figure 10 represents data from all bird measurements during the period including recaptures. Figure 11 shows only those birds measured once or those birds whose repeat measurements were separated by at least thirty days. Assuming that the biological half-life determined for the Blue Jay is roughly applicable to the Bobwhite as well, the thirty-day interval provided a time-span equivalent to five half-lives between measurements which, were there no further $^{137}Cs$ intake, would reduce the body burden by a factor of 32. It seemed reasonable to treat those particular recaptures (i.e., those separated by at least thirty days) as independent measurements. Although the distributions were changed somewhat by the inclusion or exclusion of the repeats, the statistical significance of the data when subjected to analysis of variance was unchanged.

During the period November, 1973 to September, 1974, the distribution of body burdens at the reactor trapping sites remained relatively constant ($p > 0.90$; $F = 0.377$; $df = 1,116$), but from October, 1974 to February, 1975 there was a change in the distribution ( $p < 0.001$) producing a marked skewness toward lower $^{137}Cs$ body burdens. Comparable changes in the $^{137}Cs$ body burden distributions were not observed at control site K ( $p > 0.75$; $F = 0.026$; $df = 1, 28$) although there was a noticeable broadening of the distribution. It seems evident that the reactor site body-burden distribution changes cannot be associated with reactor operations beeause from November, 1973 to March, 1974 (first distribution period illustrated) the reactor was completely shut down for repair and refuelling. Recall that it was during this

Figure 10 (following page)

Comparison of the temporal variations in the distribution of $^{137}Cs$ body burdens between the reactor trapping sites and control site K. "N" represents the total number of birds in the period. Body-burden intervals are expressed in multiples of 0.06pCi/g, the approximate $^{137}Cs$ detection limit for these birds. The data for this figure includes all birds caught during the relevant time periods, regardless of remeasurement frequency.

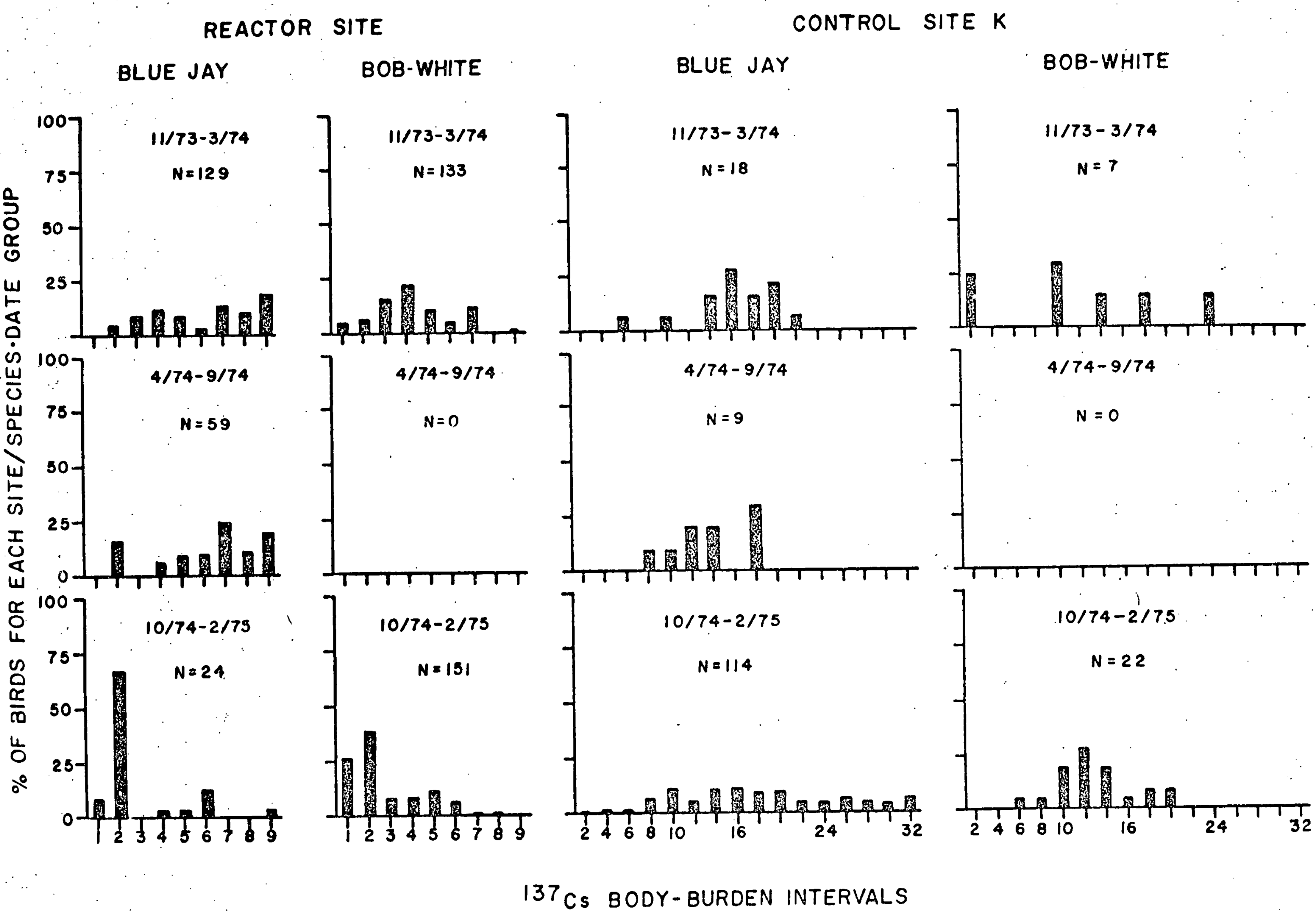
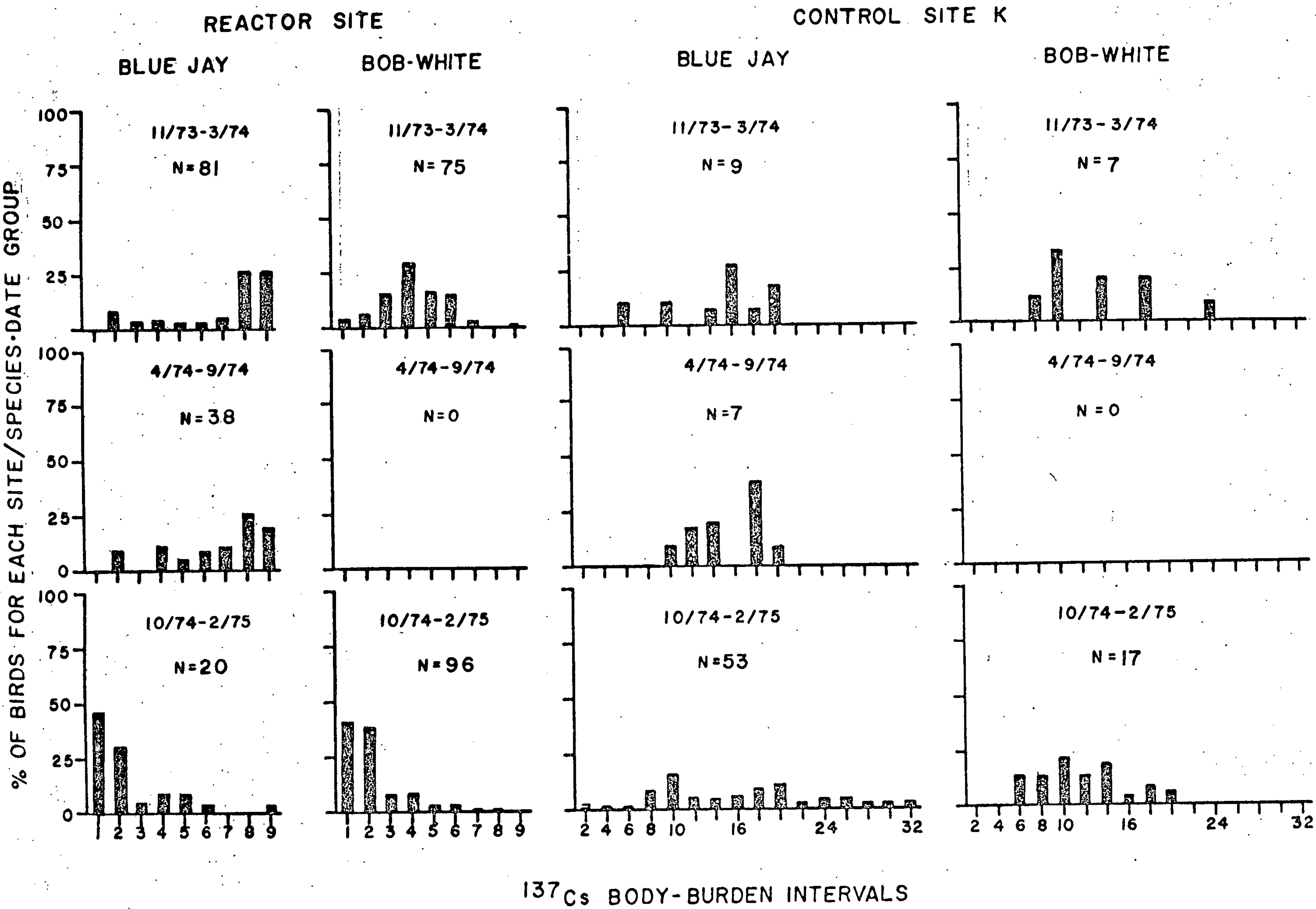

REACTOR SITE
CONTROL SITE K
BLUE JAY
BOB-WHITE
BLUE JAY
BOB-WHITE
% OF BIRDS FOR EACH SITE/SPECIES·DATE GROUP
100
75
50
25
0
11/73-3/74
N=129
N=133
N=18
N=7
4/74-9/74
N=59
N=0
N=9
N=0
10/74-2/75
N=24
N=151
N=114
N=22
1 2 3 4 5 6 7 8 9
2 4 6 8 10 16 24 32
137Cs BODY-BURDEN INTERVALS

Figure 11 (following page)

Comparison of the temporal variations in the distribution of $^{137}Cs$ body burdens between the reactor trapping sites and control site K. "N" represents the total number of birds in the period. Body-burden intervals are expressed in multiples of 0.06pCi/g, the approximate $^{137}Cs$ detection limit for these birds. The data for this figure includes only those birds measured once, or, if repeats, those measurements separated by at least 30 days, corresponding to $\sim$5 biological half-lives for $^{137}Cs$ in the Blue Jay.


REACTOR SITE
CONTROL SITE K
BLUE JAY
BOB-WHITE
BLUE JAY
BOB-WHITE
11/73-3/74
N=81
11/73-3/74
N=75
11/73-3/74
N=9
11/73-3/74
N=7
4/74-9/74
N=38
4/74-9/74
N=0
4/74-9/74
N=7
4/74-9/74
N=0
10/74-2/75
N=20
10/74-2/75
N=96
10/74-2/75
N=53
10/74-2/75
N=17
% OF BIRDS FOR EACH SITE/SPECIES·DATE GROUP
$^{137}$Cs BODY-BURDEN INTERVALS

period that the $^{131}I$ was detected, as described earlier. During the period of the reported $^{137}Cs$ decrease (illustrated as the third distribution period) the reactor was in normal operation. Figure 12 shows the average reactor power level versus time for the periods under discussion. The power level information was supplied through the courtesy of the Boston Edison Company.

The changes in the distributions in $^{137}Cs$ body burdens could be attributed to either a decrease in the body burdens of the resident avian population or to an influx of new birds with substantially lower $^{137}Cs$ body burdens. Figure 13 shows by repeat measurements on a representative set of the same individuals that the body burdens of the resident population was decreasing and that the change was not due to an influx of new birds. Moreover, the banding data supported this conclusion in that they did not show an incidence of new, i.e., unbanded birds. Figure 13 shows a similar set of repeat measurements on reactor-site birds for a comparable period one year earlier; these are seen to be essentially constant or changing only slightly with time.

The $^{137}Cs$ body-burden decreases calculated using data from repeat measurements on 34 birds corresponded to an effective half-life of 24.1 days using the total body burden of the bird. The descriptive equation is $A = Ke^{-0.0294t}$, $r = -0.820$, where A is radionuclide activity, t is time in days, and r is the correlation coefficient. Using the activity per unit mass (pCi/g), the effective half-life for the same group of birds was 27.5 days ($A = Ke^{-0.253t}$, $r = -0.937$). This significant decrease (comparing the reactor site birds, first and third distribution periods; for Blue Jays, $p < 0.001$; $F = 12.2$; $df = 2, 136$; for Bobwhite, $p < 0.001$; $F = 15.8$; $df = 1, 169$) only at the reactor site remains unexplained. The $^{137}Cs$ burdens at control site K remained approximately the same as in the previous year ($p > 0.99$; $F = 0.124$; $df = 1, 18$); birds from the new control site (BT) showed no $^{137}Cs$ body-burden anomalies when compared to control site K ($p > 0.90$; $F = 0.310$; $df = 1, 42$). In addition to the Blue Jays and Bobwhite tabulated, Brown Thrashers and Grey Squirrels from the reactor site showed

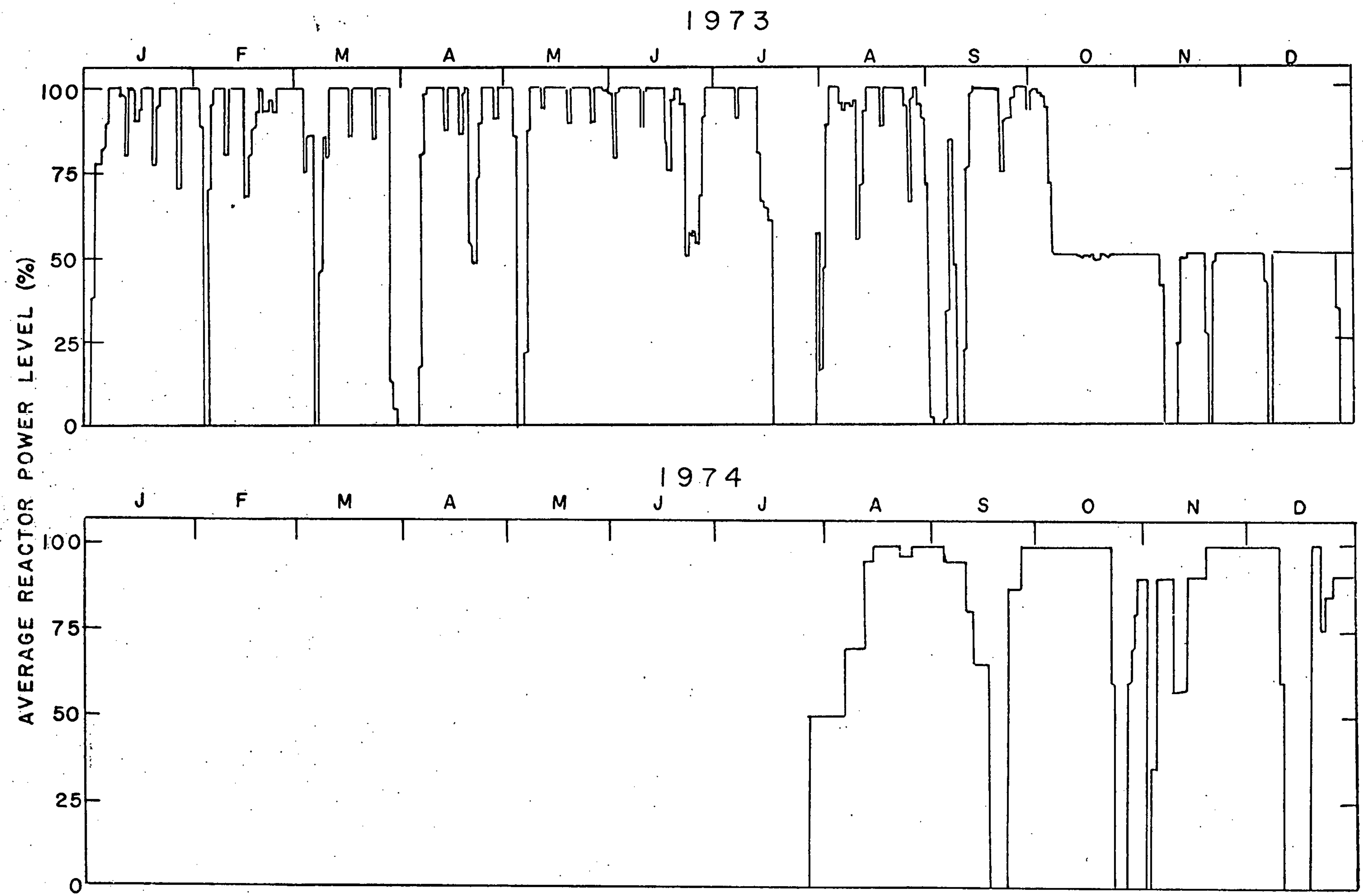



Figure 12. Pilgrim Nuclear Power Station - Operating Summary, 1973-1974

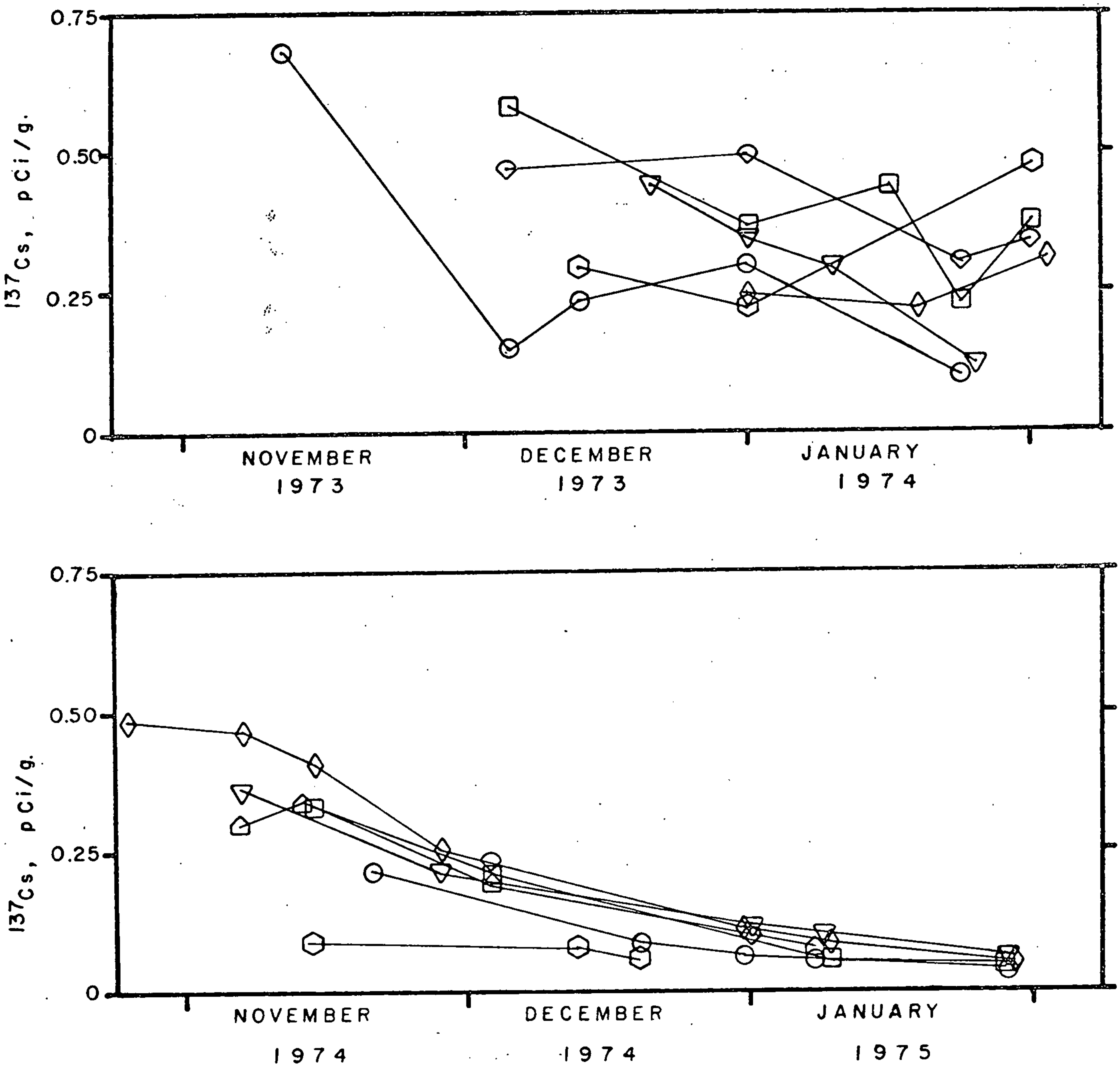



Figure 13. $^{137}$Cs body burdens in Bobwhite and Blue Jays from the reactor trapping sites. This figure illustrates the decrease in body burdens observed during the November, 1974 to January, 1975 period (lower figure) as compared with the same species at the same sites one year earlier (top figure). Illustrated are only a representative sampling of the total birds measured.

similar $^{137}Cs$ body-burden decreases.

No unusual weather was noted during the period of the reported decreases, nor did any alteration in site use by man occur. Although it is well known that dietary potassium levels have a significant effect on cesium uptake, it remains difficult to conceive of a mechanism which would cause a major alteration in the diets of four animal species (three avian, one mammalian) which did not occur in past years. It is even more difficult to accept that this postulated mechanism would operate on these four species only in a very limited geographical area. The probability of a transient meteorological phenomenon producing a highly localized environmental alteration which would endure for at least four months seems unlikely, especially given the short $^{137}Cs$ biological half-life and reaccumulation rate of the birds involved. Further mathematical analysis of the data resulted in the derivation of the environmental component of the decrease function. The work and its results are described in the section reporting on the 1975-1977 portion of the program.

13. <u>Inquiry Into Age and Sex Differentiated Nuclide Uptake</u>

Prior research had indicated that both age and sex might affect uptake of radionuclides in many animals. Accurate age and sex information would be essential if any determination of age and/or sex differentiated radionuclide uptake were to be attempted.

The determination of age and/or sex in birds is highly dependent on species and season (Wood, N.D.). A few species may be aged and sexed throughout the year. This is especially true of the larger species, including game birds. Some other species, even during the breeding season when variable sexual characteristics attain their greatest prominence, are totally inseparable without making an internal examination of the bird's sexual organs. A significant proportion of the species with which this research program has dealt simply do not offer characteristics which, based on current knowledge, can be used to make accurate age and/or sex determinations at all times.

Often, extensive examination of preserved museum specimens which have been classified as to age and sex by disection will reveal subtle external differences which may be used as age or sex determinants in living birds. However, these determinants are frequently discarded when subsequent study indicates that, e.g., the researcher was dealing with examples confined to a local race and that the noted characteristics do not apply to the species as a whole. As a result, depending on the state of current research, a species which might have been aged confidently a year ago may now be considered undifferentiable. This is a serious and continuing problem in passerine bird research. Because of the rapid changes in acceptable criteria, many researchers, especially bird banders, continue to take extensive biometric data even though its utility may be questionable, in case evidence of new determinants may make such data useful, or, more rarely, in case a discarded formula regains credibility.

The Bobwhite may be differentiated with a good deal of confidence. From our Bobwhite data a sample of 95 birds of known sex captured at the reactor trapping sites was drawn. This sample population comprised all Bobwhite of known sex captured between November, 1973 and March, 1974, at which time the Bobwhite population becomes relatively inaccessible due to increased availability of natural food and breeding season dispersal. This sample population was relatively evenly divided sexually, consisting of 51 females and 44 males. A comparison of the $^{137}Cs$ body burdens of these birds revealed no differentiation; for the females, the body burdens averaged 0.21 pCi/g with a standard deviation of 0.11 pCi/g; the range was 0.03 - 0.49. The comparable data for the males was 0.21 $\pm$ 0.09 pCi/g, range; 0.01 - 0.42.

For the Blue Jay, on the other hand, very few reliable characteristics are available for distinguishing age or sex. For example, during the breeding season, both the males and the females develop brood patches; only the clear presence of a cloacal protuberance allows the sexual differentiation of the male or a palpable forming egg (rare) the female. Otherwise, Blue Jays must be classified as of unknown sex. Until recently, the distinctness of color barring on certain flight feathers (alula and alular coverts) was accepted as a valid age criterion. This criterion has now come into some question, and the Banding Office of the U.S. Fish and Wildlife Service has requested banders to provide all possible additional data in an attempt to resolve the question of the validity of the age determinant.

A sample of 32 Blue Jays trapped at control site BT over a five-week period showed a significant relationship between age (as determined by the alular barring technique) and $^{137}Cs$ body burdens. These birds, trapped between 20 February and 27 March, 1975 were all in at least their second year.* The ageing technique allowed the division of this group into 18 second year (SY) birds, 13 after-second-year (ASY) birds, and one bird of unknown age. The mean $^{137}Cs$ body burden of the SY birds was $0.10 \pm 0.13$ pCi/g, and for the ASY birds, $0.92 \pm 0.57$ pCi/g. Subjected to a one-way analysis of variance, these age-dependent differences proved to be very significant ( $p < 0.001$; $F = 13.9$; df = 1, 29).

14. <u>Appearance of Significant $^{95}Zr$-$^{95}Nb$ in One Catbird</u>

The detection of $^{95}Zr$-$^{95}Nb$ for limited periods following Chinese atmospheric nuclear tests has already been discussed. Of related interest, during the period July, 1974 through June, 1975, more than 250 Catbirds were measured in the whole-body counting laboratory. Of this group of Catbirds, only one showed detectable $^{95}Zr$-$^{95}Nb$. However, its body burden ($1.08 \pm 0.07$ pCi/g) was the highest seen in any bird at any

* The ageing of birds assumes a 1 January date of birth. During its first year a bird is called a hatching year (HY) bird. On the following 1 January, the bird becomes an after-hatching-year (AHY) bird. If ageing characteristics are available to differentiate birds in their second year from still older birds, the terms second year (SY) and after-second year (ASY) are used, etc.

time during the project. This bird was held for biological half-life measurements. The result (69.9 ± 15.6 days) was essentially the same as the physical half-life for this isotope pair (65.5d). The bird was measured ten times during its first twelve days of captivity. Between the twelfth and fourteenth days the $^{95}Zr$-$^{95}Nb$ level in this bird suddenly fell to below detection limits, decreasing by at least a factor of thirteen. The sudden drop suggested that the nuclide was present in particulate form on the feathers or, more likely, in the air-sac system connecting with the bird's lungs, and that the particle was expelled or dropped between the twelfth and fourteenth days. We were unable to detect any $^{95}Zr$-$^{95}Nb$ activity in the collected droppings from the cage floor, in the cage cover sheet, or in careful wipes of the entire cage structure. Thus the source and the ultimate fate of this relatively high level of $^{95}Zr$-$^{95}Nb$ in a single Catbird remains unknown. As will be noted from the intercomparison data discussion above, Perkins found levels of this isotope pair in a number of the birds sent to him for measurement suggesting that $^{95}Zr$-$^{95}Nb$ may be more widely distributed in birds than our less sensitive measurements indicate. This possibility however does not help to explain the sudden appearance of $^{95}Zr$-$^{95}Nb$ at nearly 16 times detection limit in a single Catbird.

15. Sample Collection at Other Reactor Sites

At the suggestion of the AEC DBER we undertook a determination of the feasibility of extending our radionuclide measurements to samples from remote sites. Beyond a radius of about 75km, the capture, measurement, and subsequent return for release of live birds would be impractical. However, we felt that it would be practical to send out a field team to survey, trap and collect (i.e., kill) a small but representative sample of the avifauna from a remote site. The collected specimens could then be returned to the radionuclide measurement laboratory for study. We recognized that this procedure has all of the drawbacks of the typical grab-sample techniques which our repetitive non-destructive methods have minimized, but if transient phenomena required the rapid assessment of avifauna in a remote area, this destructive sampling could provide a useful first step.

In order to make the excercise as realistic as possible we assumed that a quick reaction was essential. The only factor which took any significant time was the securing of permission to operate on the selected reactor sites. Should conditions arise requiring the rapid assessment of radionuclides in avifauna under the direction of a regulatory agency, we assume that this delay would be eliminated by circumstances. No other advance preparations were made; no personnel schedules were altered in readiness, and the necessary permits to engage in scientific collecting in new areas had not been issued to MBO.

We chose to work at two of the reactors of the New England Yankee electric system, Maine Yankee at Wiscasset, Maine and Vermont Yankee at Vernon, Vermont. These stations are 240 and 190 kilometers respectively from MBO. Once permission to work on the sites had been granted, we began the excercise.

Our first order of priority was to dispatch a field biologist to the areas to survey and select trap sites. We simultaneously contacted state and Federal authorities for the necessary permits to collect birds. The Federal Banding Office is responsible for the issuance of permits necessary for the live trapping of migratory birds. The Fish and Wildlife Service through the regional Game Management and Law Enforcement District is responsible for collecting (taking by killing) permits. Each individual state must then issue covering permits for each of the Federal permits, both collecting and banding. State permits are usually issued only after the state receives notification of the issuance of a Federal permit. The response time of this potentially unwieldy bureaucratic maze was outstanding. It was made clear by the various licensing authorities that in the case of real need, temporary telephone authorizations would be issued. In fact, seemingly in the spirit of the excise, telephone verifications were made between the Federal agencies and several of the states. The first of the state permits were in hand less than 36 hours after the initial requests.

While the permits were being secured, the field biologist had made his initial contacts with reactor station personnel and selected and baited trap sites after observing local bird populations with respect to the reactor locations. Of course, if the need for urgent data existed, birds could be collected by shooting. Bait was left with reactor station personnel who were requested to bait the selected sites lightly each day for a few days to develop a stable trap clientele. The biologist then returned to MBO, picked up traps and permits as well as insulated containers in which to ship the collected birds, then returned to the reactor sites to collect the samples.

Ten birds were collected at the Vermont Yankee site, eleven in Maine. They were brought back to MBO sealed in plastic bags, packed in ice. Dry ice could have been used; we contacted a number of suppliers to establish year-round availability, but felt that for the purposes of this excercise dry ice represented a needless effort and expense. The collected birds were measured as routine specimens in the whole-body counting laboratory. The measurement results are presented in Table 6. The small birds collected at the remote sites were combined as shown for initial measurements. Had the composite spectrum shown activity significantly different from similar species measured live, individual measurements would have been made. Composite measurements are not a normal procedure at the radionuclide measurement laboratory, but since the point of the entire excercise was a determination of logistical problems, composite measurements were deemed acceptable.

This effort demonstrated that it is feasible to move rapidly to the site of a reactor (or any other area of interest), observe and collect a representative sample of the avifauna and return the specimens for radionuclide measurement. Questions as to just which of the observed species were typically resident were answered by checking with local banders identified by the Banding Office. In both cases described here, local banders were available who were able to supply valuable

| Site | Species[1] | n | Total Wt. (g) | $^{131}I$ (pCi/g) | $^{137}Cs$ (pCi/g) | $^{95}Zr-^{95}Nb$ (pCi/g) | K (g/kg) |
|---|---|---|---|---|---|---|---|
| Wiscasset, Me. | SOSP, WTSP | 4 | 104.5 | $0.05 \pm 0.06$ | $0.25 \pm 0.07$ | $< 0.01$ | $3.42 \pm 0.50$ |
| " " | WCSP, WTSP SOSP | 6 | 165.2 | $0.09 \pm 0.04$ | $0.18 \pm 0.05$ | $< 0.02$ | $3.18 \pm 0.32$ |
| Vernon, Vt. | WCSP | 6 | 225 | $0.05 \pm 0.03$ | $0.07 \pm 0.03$ | $< 0.02$ | $2.21 \pm 0.23$ |
| " " | WCSP | 5 | 167.6 | $0.04 \pm 0.04$ | $0.10 \pm 0.04$ | $< 0.01$ | $3.61 \pm 0.32$ |

1 SOSP: Song Sparrow, WTSP: White-throated Sparrow, WCSP: White-crowned Sparrow

TABLE 6. Summary Body-Burden Data for Birds Collected at Maine and Vermont Reactor Sites.

information concerning the avifauna of the reactor sites.

If distances to intended sites of operation are greater than practical driving distance, the field biologist could take all necessary equipment with him by air and ship collected birds back the same way. The shipping boxes used in this experiment were designed for the air shipment of biological specimens packed in dry ice. The only practical difficulty with the air-travel scheme would be the difficulty of transporting firearms should a rapid collected-by-shooting sample be required.

## III. FIELD AND LABORATORY ACTIVITIES, MATHEMATICAL MODELLING (Other Than Metabolic Studies)

Trapping sites continued to be those reported in previous years. Delays in initiating the construction of the second reactor at the primary site ensured that no new disturbances affected the local avifauna. In addition, a concerted effort by the Boston Edison Company to hold clearing and other habitat alterations to an absolute minimum in the construction of Pilgrim Unit II has made it clear that neither of the two reactor-site net lanes will be materially affected by future construction activities.

Terminating the field work and the associated laboratory work on 1 April, 1976 materially decreased the total number of birds handled, especially missing the heavy spring migration period. As a result, the field totals for this reporting period are less than in previous years; 2048 birds of 80 species were trapped or netted by the field staff. Of these, 866, or 42% were repeats (previously banded birds). No species whose appearance in this area might be considered unusual from an ornithological standpoint were caught this year.

The radionuclide measurement laboratory performed whole-body counts on 467 of the 2048 birds caught. In addition, 16 small mammals were processed. Although 29 avian species were represented in the laboratory measurements, Blue Jays, Bobwhites, and Catbirds made up 64% of the total. Of the birds measured in the laboratory, 36% had been radioassayed at least once previously. Measurement results proved to be essentially a continuation of the results reported in the past; no unusual radionuclides or abnormal levels were detected. However, the levels of $^{137}Cs$ in birds at the reactor trapping sites which had been observed to be decreasing at the end of 1974 and the beginning of 1975 (as reported in the last progress report) have returned to what we have come to term "normal," i.e., levels approximating those observed during the period from 1971 to mid-1974. We are still unable to explain this sudden, uniform, well-documented decrease of $^{137}Cs$ burdens in this limited geographic area.

As was pointed out in the last Technical Progress Report, the decrease in $^{137}Cs$ body burdens of birds taken from the nuclear power station sites conformed to an exponential decay curve with the equation

$A = A_o e^{-0.0253t}$, with a half-life of 27.5 days. This equation is, of course, the resultant or composite of two superimposed processes presumably represented by exponential decay functions. One of these functions describes the environmental change (or, equivalent to the same effect, the change in the quantity of material accessed or ingested by the birds under study). The second function quantifies the biological excretion of the material once it has been ingested by the bird. Each of these functions may in turn be resultants of more than one component; both physical decay and weathering, for example, in the case of the environmental component, and gut and tissue elimination rates may be present in the biological component.

As has been reported, many of the birds in which this decrease in $^{137}Cs$ burdens was observed were Blue Jays. From previous studies, we had determined that the biological half-life of $^{137}Cs$ in the Blue Jay is 6.7 days. However, knowing one of the two input exponential decay functions and the resultant composite decay function is not sufficient to determine explicitly the second input exponential decay function through any general solution. We were thus forced to create an iterative solution to the problem based on the following relationships:

Environmental activity at time 0: $A_{E_o}$ (activity/unit area)

Environmental activity at time t; $A_{E_o} e^{-\lambda_1 t}$

Where $\lambda_1 = 0.693/k_1$; $k_1$ is the environmental half-life

Note: $k_1$ may be a composite of a number of functions, some of which may not be exponential, e.g., weathering effects

Activity absorbed by bird: $I = Rca$ (Ci/unit time)

Where R = rate of food intake (g/unit time)

c = radionuclide concentration in food (Ci/g)

a = fraction of ingested activity which is absorbed

$c = f(A_E)$, and thus $I_t = f(A_{E(t)})Ra$ ( f = "function of")

R and a will be species-dependent (indeed, to some extent, dependent on the individual bird) but environment independent. On the other hand, c will depend both on the environment and on the food choices of the individual bird. For the purposes of our analysis, c is assumed proportional to $A_E$, and $A_E$ is defined as the activity levels in the bird's feeding environment; the proportionality constant (f) relates the food to the activity per unit area. We do not at this point have sufficient data to define these quantities.

Body burden of bird at time t: $Q_t = \Delta I_t + Q_{(t-1)}e^{-\lambda_2} =$

$$[f(A_{E(t)})Ra] + Q_{(t-1)}e^{-\lambda_2} \quad (Ci)$$

Where $\lambda_2 = 0.693/k_2$; $k_2$ is the biological half-life of radionuclide in the bird

$\Delta I_t$ = quantity of radionuclide taken in during a single time unit (t)

As with $k_1$, $k_2$ is a composite of more than one function, the physical decay and the biological half-lives of the body burdens.

Body burden at t = 0 assuming no initial body burden:

$$Q_{(t=0)} = \Delta I_t = f(A_{E_o})Ra \quad (Ci)$$

Body burden at t = 1: $Q_{(t=1)} = [\Delta I_{(t=1)} + Q_{(t=0)}e^{-\lambda_2}] =$

$$[f(A_{E_o}e^{-\lambda_1})Ra] + [f(A_{E_o})Ra]e^{-\lambda_2} \quad (Ci)$$

Body burden at t = 2: $Q_{(t=2)} = [\Delta I_{(t=2)} + Q_{(t=1)}e^{-\lambda_2}] =$

$$[f(A_{E_o}e^{-2\lambda_1})Ra] + [f(A_{E_o}e^{-\lambda_1})Ra]e^{-\lambda_2} + [f(A_{E_o})Ra]e^{-2\lambda_2} \quad (Ci)$$

Body burden at t = n: $Q_{(t=n)} = [\Delta I_{(t=n)} + Q_{[t=(n-1)]}e^{-\lambda_2}] =$

$$[f(A_{E_o}e^{-n\lambda_1})Ra] + [f(A_{E_o})Ra]e^{-n\lambda_2} + [f(A_{E_o}e^{-\lambda_1})Ra]e^{-(n-1)\lambda_2} +$$

$$[f(A_{E_o}e^{-2\lambda_1})Ra]e^{-(n-2)\lambda_2} + [f(A_{E_o}e^{-3\lambda_1})Ra]e^{-(n-3)\lambda_2} +$$

$$\ldots\ldots\ldots + [f(A_{E_o}e^{-(n-1)\lambda_1})Ra]e^{-\lambda_2} \quad (Ci)$$

In general, the body burden Q at any given time t is found by adding the radionuclide input for day t, designated $\Delta I_t$, to the body burden from the previous day after subtracting the appropriate quantity from excretion and physical decay as determined by the parameter $k_2$ from that earlier body burden. Thus the generalized form of the equations above is:

$$Q_{(t)} = \Delta I_{(t)} + Q_{(t-1)}e^{-\lambda_2} \quad (Ci)$$

This equation was used in the iterative program.

The program was developed to accept a wide variety of plausible environmental conditions as input parameters in order to maximize the utility of the program as an environmental model. In addition to environmental activity at time zero ($A_{E_o}$) which is defined as the activity level in the bird's feeding environment, the environmental decay rate ($k_1$), biological decay rate or biological half-life ($k_2$), fraction of ingested activity absorbed ($a$) and initial body burden may be specified. $\Delta I_t$ is specified as a fixed fraction of $A_{E(t)}$. The environmental activity may be incremented by a finite amount with each successive unit time period and/or a single release of defined magnitude may be programmed to occur at a preselected time. Program outputs are, for each time unit, environmental activity ($A_E$), total released activity, total absorbed activity, and body burden.

In the case of the $^{137}Cs$ body-burden decreases, body burden and biological half-life were known, and no incremental increases were assumed in the environmental radionuclide levels. In addition, the 30-year half-life of $^{137}Cs$ meant that physical decay of the radionuclide had no significant effect. Various values for $k_1$ inserted into the program thus represented the rate of change in the presence or availability of $^{137}Cs$ to the birds. The resultant value for the body burden at each time increment was observed and, after allowing the model bird to reach equilibrium with the environment, a value for $k_1$ was found for which the slope of the body-burden curve was equivalent to that from our field data, a half-life of 27.5 days. The equation thus determined for the environmental decay rate is $A=A_{E_o}e^{-0.0289t}$ corresponding to a half-period of 24 days.

Figure 14 is a plot of program output for the case $k_1$ = 24d and $k_2$ = 6.7d, which produced the result most closely matching the field data. Additional figures (15-20) are included to show the composite results produced by varying one of the two input functions ($k_1$ or $k_2$) and by varying the initial body burden. Examples of periodic incremental releases and one-time releases are also shown. Together with the data now being generated by our radionuclide retention studies (Section IV), this calculation procedure allows the evaluation of the environmental changes by the use of various birds accessing fixed or changing levels of radionuclides, whether the birds are initially at equilibrium with the radionuclide environment or just entering a newly-contaminated area.

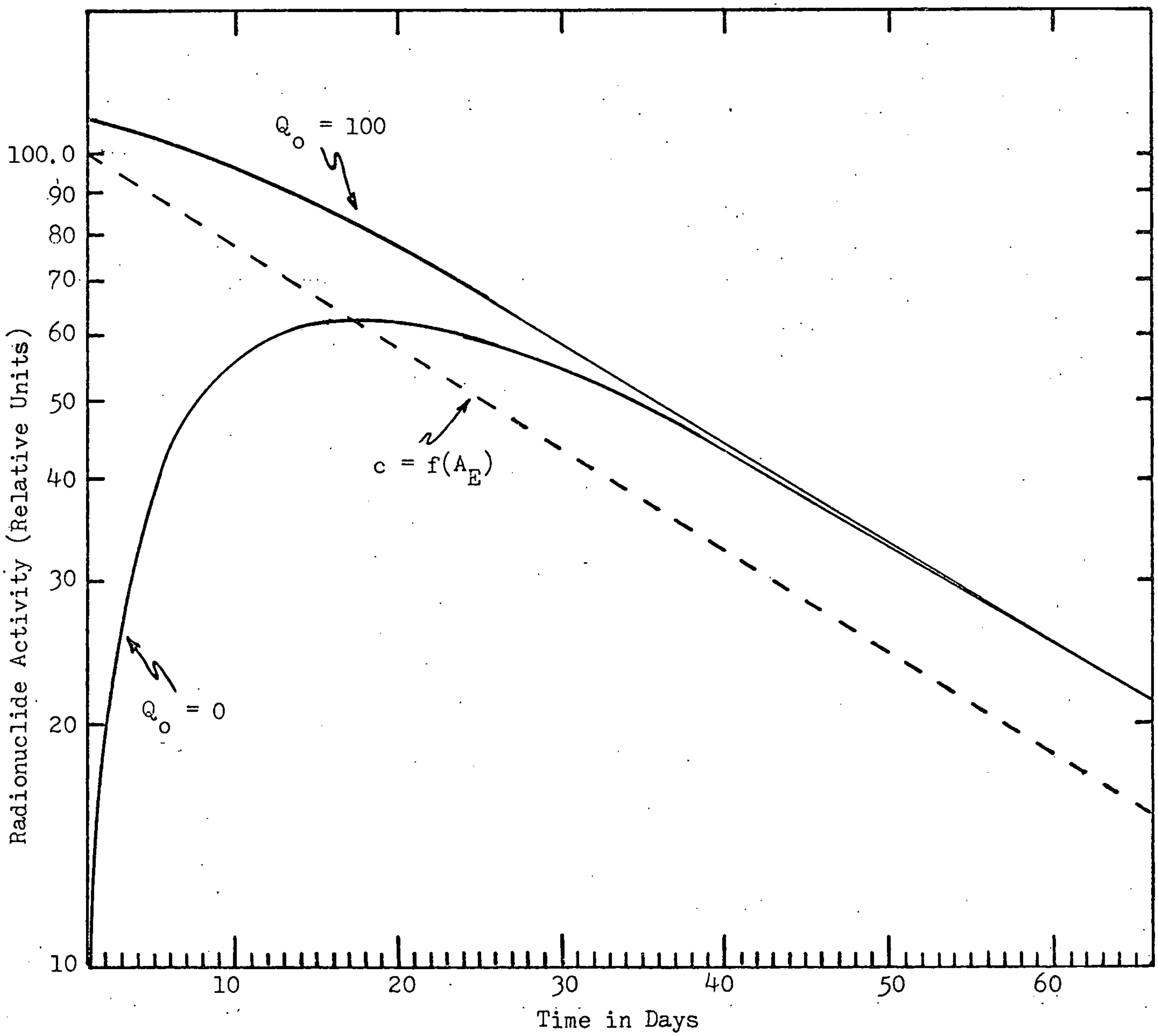



Figure 14. Relative body burden versus environmental level for the following conditions: $A_{E_o} = 100$

$k_1 = 24$ days

$k_2 = 6.7$ days

$a = 0.1$

(Refer to text for definition of variables)

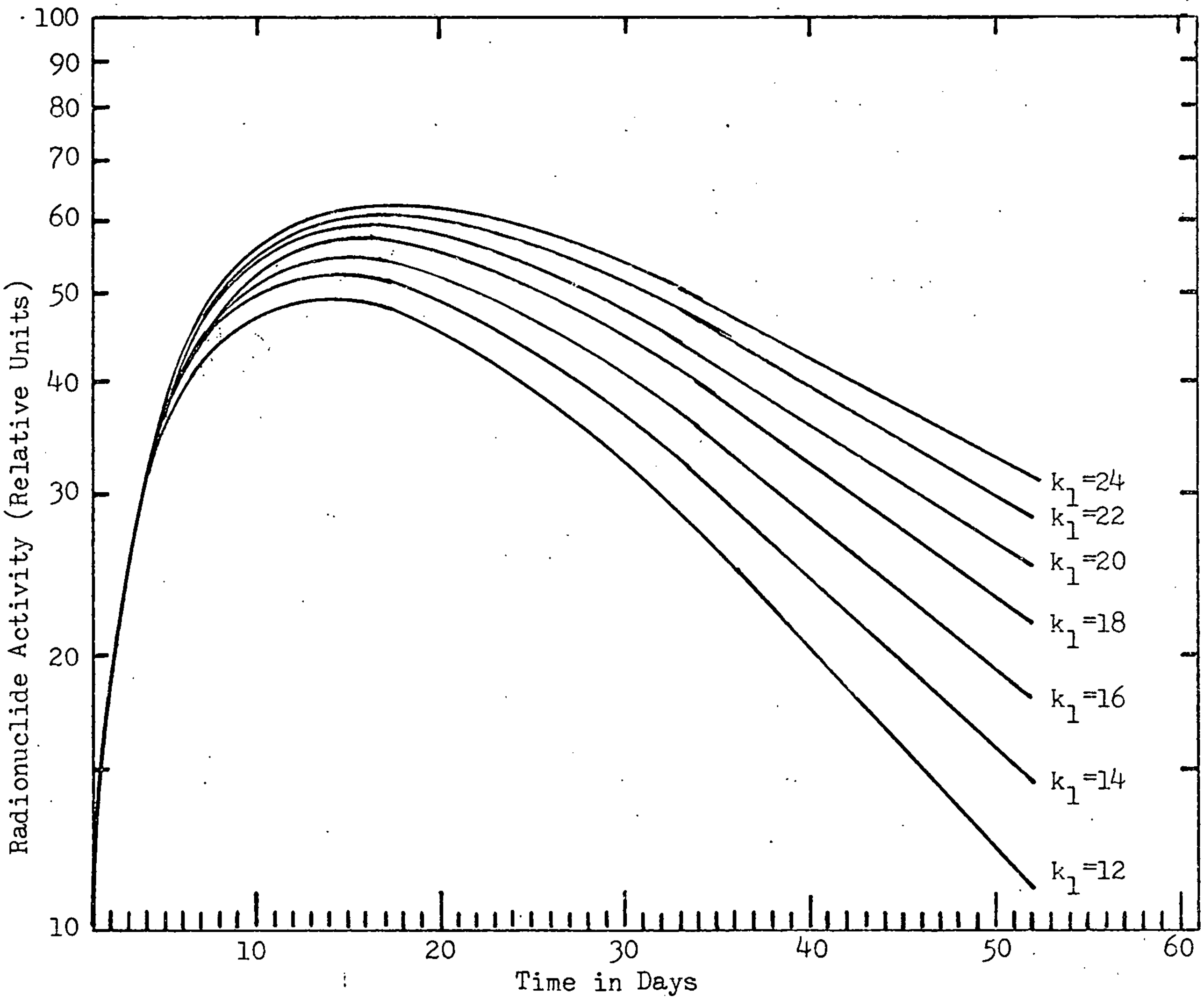



Figure 15. This series of plots represents the body burdens in a bird with an initial body burden of zero entering an environment in which the environmental radionuclide levels are decaying exponentially with a half-life of $k_1$ days. The biological half-life of the material is 6.7 days. The resultant composite half-lives are as follows:

| $k_1$ (days) | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
|---|---|---|---|---|---|---|---|
| composite $T_{\frac{1}{2}}$ | 13.5 | 16 | 18.3 | 20.5 | 22.5 | 25 | 27.5 |

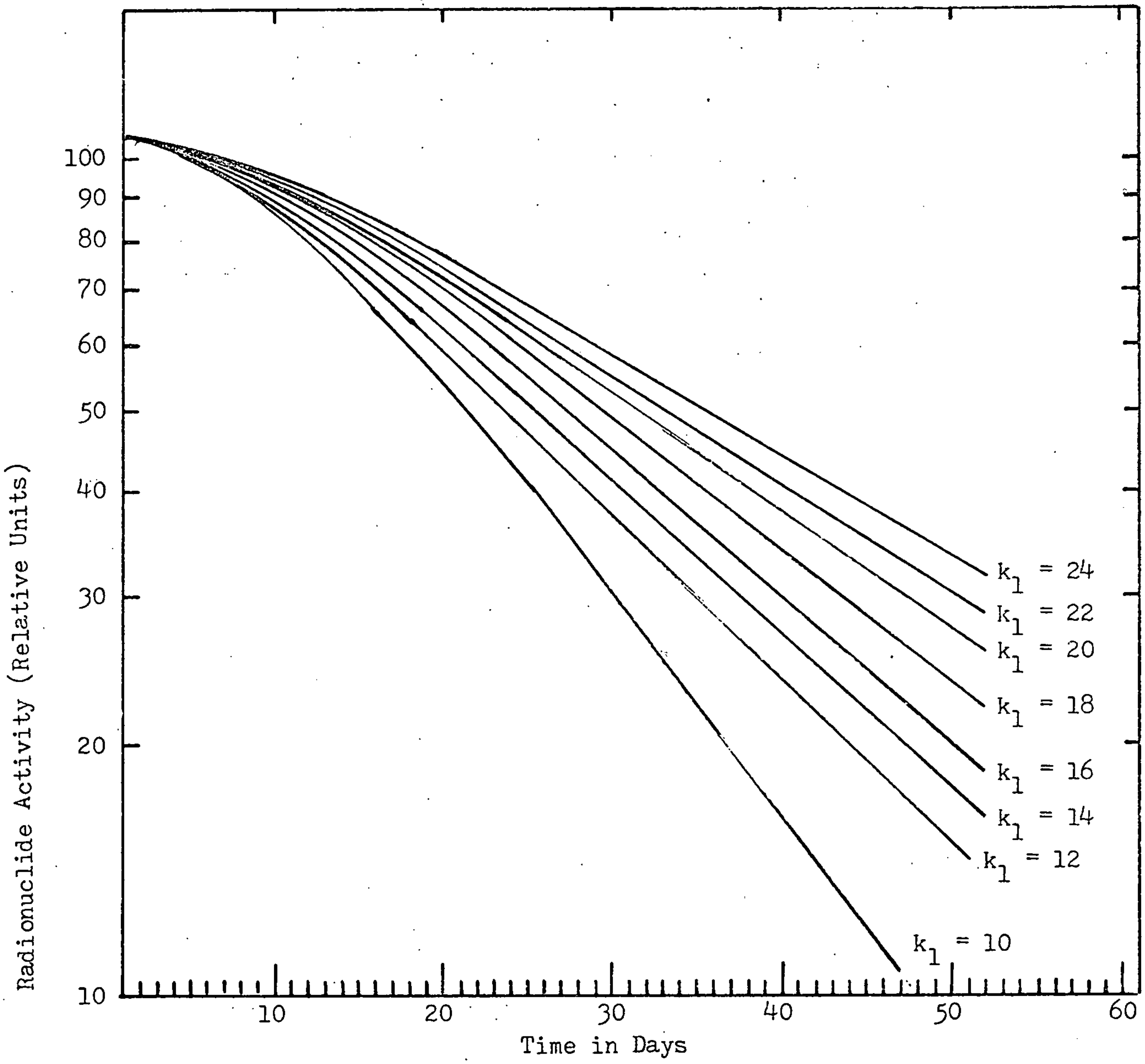



Figure 16. Radionuclide body burdens in a bird initially at equilibrium with its environment at which time the environmental level begins to decay exponentially with a half-life of $k_1$ days. The biological half-life of the material is 6.7 days. Refer to Figure 15 for the numerical value of the composite half-life associated with each value of $k_1$.

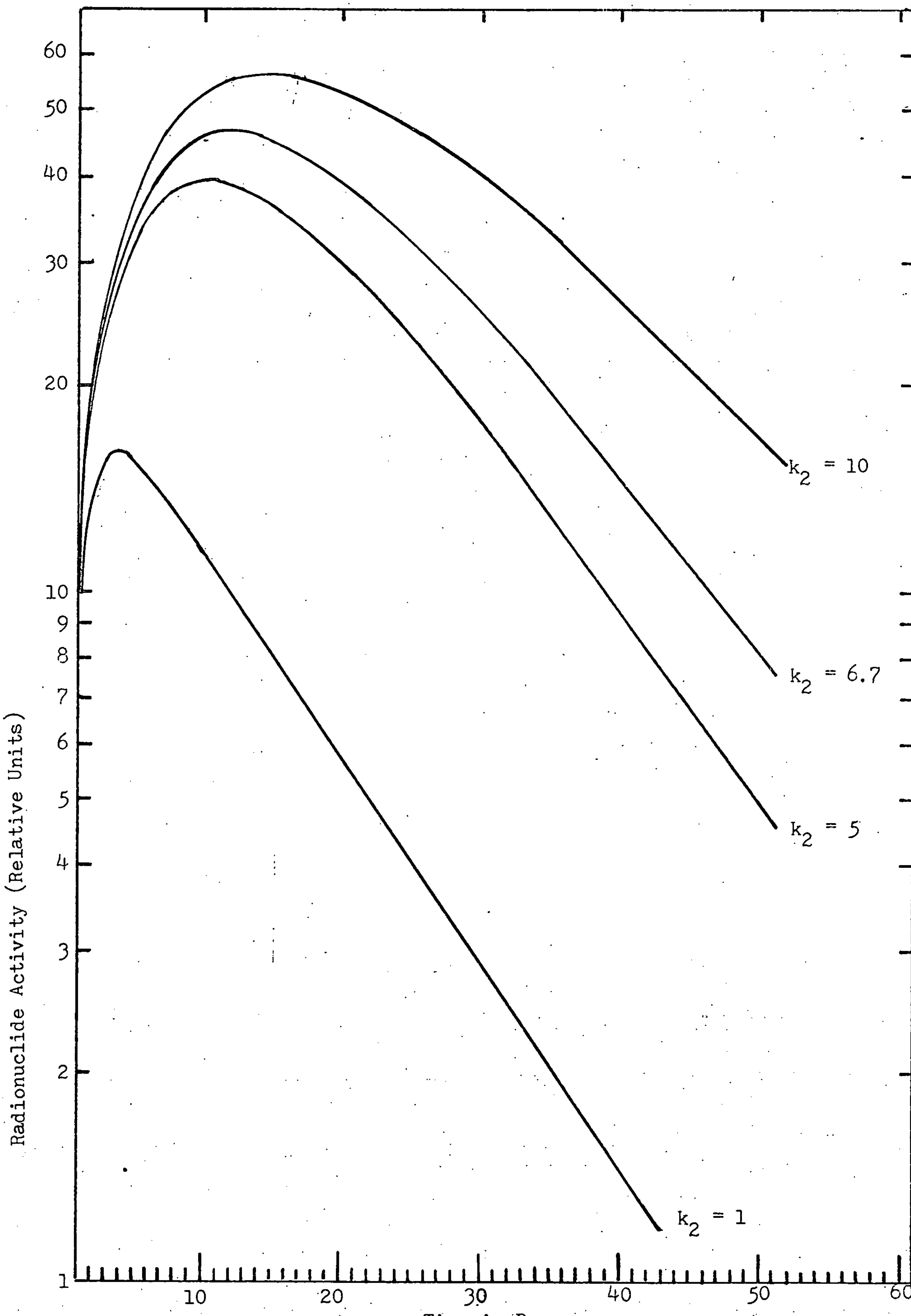



Figure 17. Body burdens in a series of birds with no initial body burden which enter an environment in which the radionuclide levels are decaying with a half-life of ten days. $k_2$ is the biological half-life.

Figure 18. Relative body burden versus environmental level for the following conditions:

$A_{E_o} = 0$

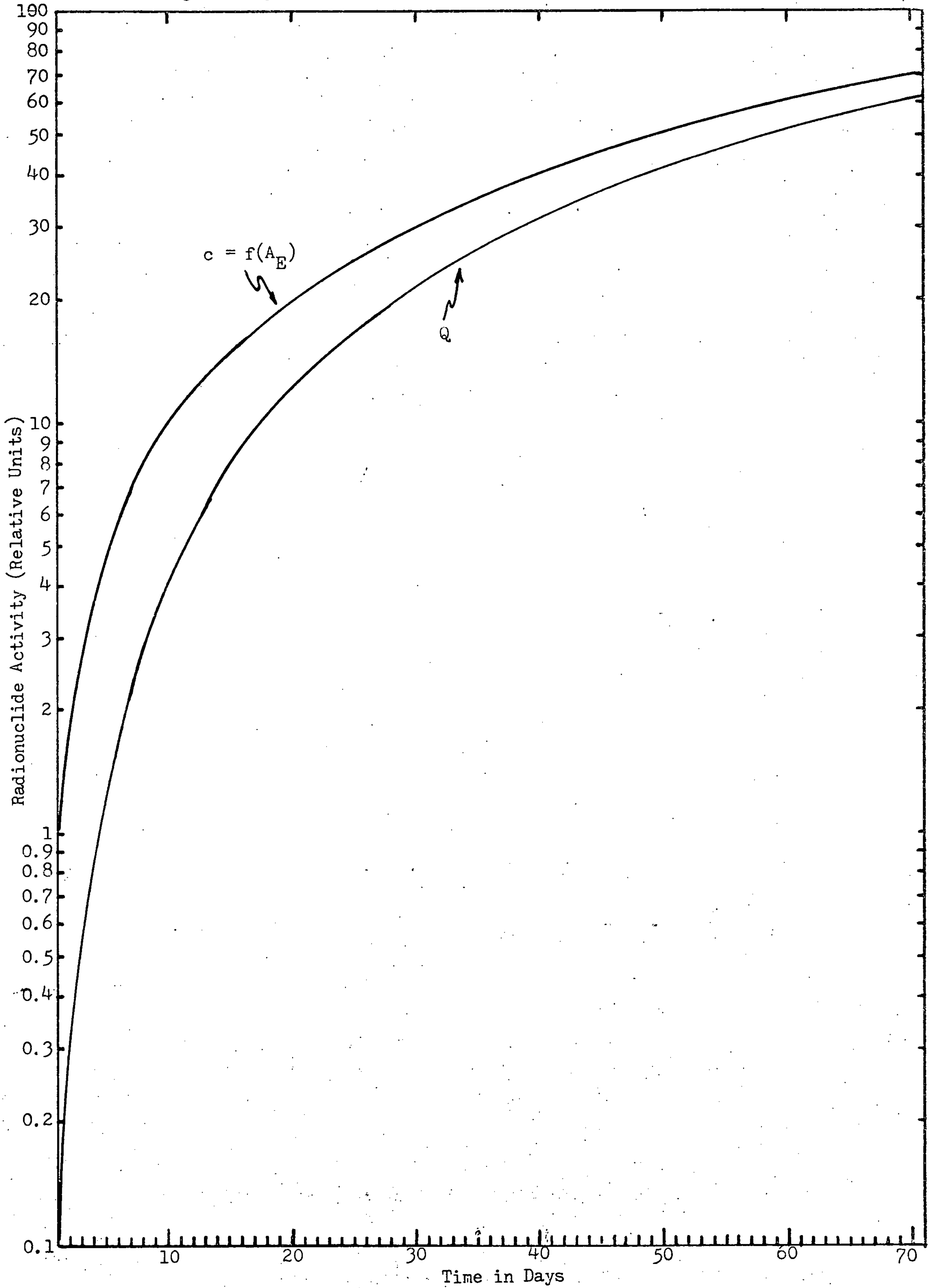
$k_1 = 30$ years

$k_2 = 6.7$ days

$a = 0.1$

$Q_o = 0$

In addition, a radionuclide release of magnitude one unit is postulated to occur each day. Refer to text for definition of variables.


100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Radionuclide Activity (Relative Units)
c = f($A_E$)
Q
10
20
30
40
50
60
70
Time in Days

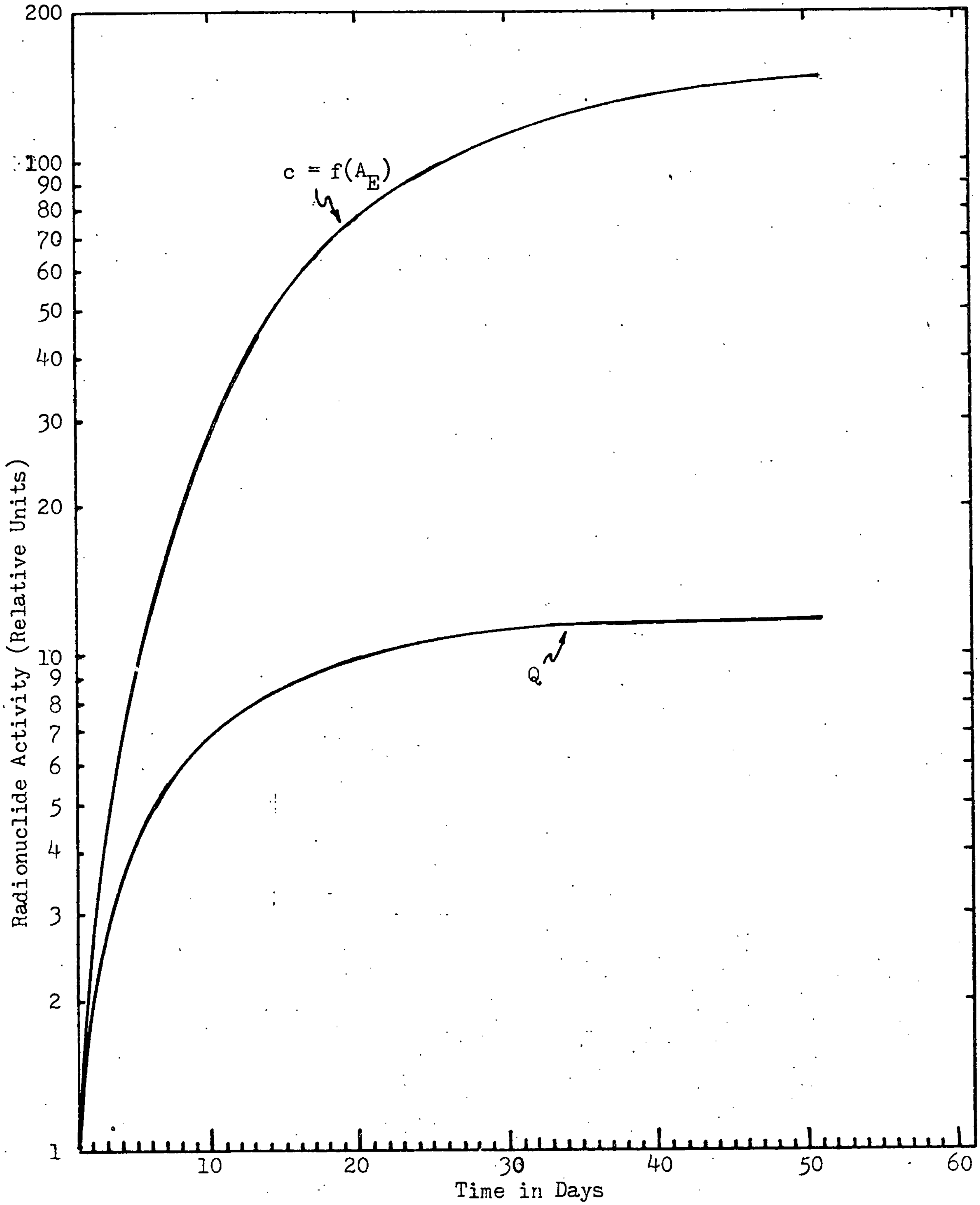



Figure 19. Relative body burden versus environmental level for the following conditions: $A_{E_o} = 0$; $k_1 = 8.05d$; $k_2 = 1.0d$; $a = 1.0$; $Q_o = 0$; and a release of one unit occurs each day. Refer to text for definition of variables.

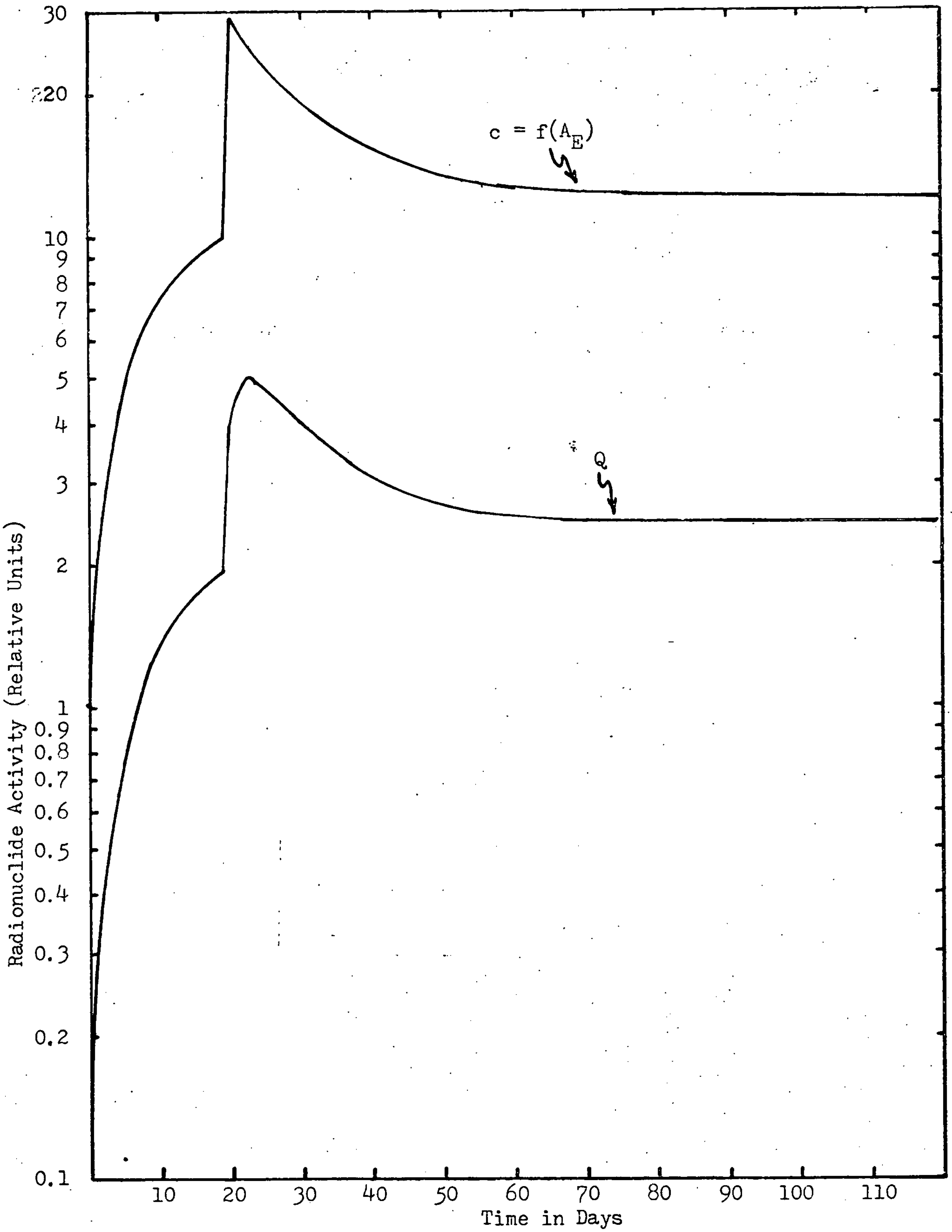



Figure 20. Relative body burden versus environmental level for the following conditions: $A_{E_o} = 0$; $k_1 = 8.05d$; $k_2 = 1.0d$; $a = 1.0$; $Q_o = 0$; a release of one unit occurs each day, and a single release of 20 units occurs on day 20. Refer to text for definition of variables.

## IV. RADIONUCLIDE METABOLISM STUDIES

In order that the techniques of repetitive non-destructive measurement of avian radionuclide body burdens be made most widely useful as an environmental monitoring tool, it was imperative that we establish the metabolic response parameters of our primary avian study species to a wide range of potential reactor release products.

A further impetus for this metabolic work came from our past experience. As has been previously reported, we have observed a consistent discrepancy in the mean $^{137}Cs$ body burdens in four avian species with considerable food-habit overlap. Individuals of two species, the Blue Jay (Cyanocitta cristata) and the Bobwhite (Colinus virginianus) have shown, almost without exception, significant body burdens of $^{137}Cs$ while Red-winged Blackbirds (Agelaius phoeniceus) and Mourning Doves (Zenaidura macroura) taken in the same nets and traps at the same times have essentially no detectable $^{137}Cs$, differences which were generally more than an order of magnitude. We felt that laboratory studies of captive individuals of these four species might help uncover the reason for this significant difference. Table 7 catalogs the food preferences of these species demonstrating the essential similarities.

Table 7. Food Habit Overlap in Four Avian Species

| | Species | | | |
|---|---|---|---|---|
| Food Type | Blue Jay | Bobwhite | Mourning Dove | Red-winged Blackbird |
| Vegetable | 75.7% | 84.0% | 90.0% | 73.0% |
| Animal | 24.3% | 16.0% | 10.0% | 27.0% |

Subdivision of Vegetable Category for Two Species

| | Species | |
|---|---|---|
| Vegetable Sub-group | Bobwhite | Red-winged Blackbird |
| Grain | 17% | 13% |
| Seeds | 53% | 55% |
| Fruit | 10% | no data |
| Other | 4% | 5% |

Tabular data taken from Bent, A. C., "Life Histories of North American Birds" Smithsonian Institution, USGPO, various dates.

Birds used in these laboratory studies were trapped or netted in conjunction with the normal field banding work (except for some Bobwhite as noted below) which supplied the samples used for the established radionuclide measurement program. Since we were unsure of the survival probability of these wild birds when caged for relatively long periods we generally avoided using any birds which had been radioassayed frequently in the past in order to avoid the possible loss of continuing field data from these birds. Some of the Bobwhite were obtained from the game-bird hatchery of the Commonwealth of Massachusetts located at Sandwich, Mass.

In the laboratory, stainless-steel small-mammal cages were used to house the birds as described in the metabolic studies section of the previous Technical Progress Report. Further modifications were made to the cages better to adapt them to bird use. The normal bar-grid floor which had been overlaid with Plexiglass was replaced with a finer grid formed of vinyl-coated wire mesh with openings of approximately 1 X 2 cm. This mesh provided a suitable walking surface for the birds and the vinyl coating allowed nearly all of the birds' droppings to fall through thus minimizing external self-contamination. The floor below the grid was covered with a removable liner consisting of an absorbent paper/polyethylene sandwich. This liner was extended well up on the sides of the cage and fastened with tape. This combination of grids and absorbent liners permitted the convienient collection of all droppings and effectively prevented the contamination of the cages or the birds through contact with their own droppings. The small amount of material which adhered to the grid floors was wiped off with an alcohol-soaked cotton swab which was then dropped on the liner. Liners were removed, folded and sealed for subsequent measurement while the bird was being measured in the whole-body counter. A new liner was inserted prior to returning the bird to its cage. Liners were counted in the whole-body counter to act as an independent measure of radionuclide excretions and to assure, through summing the bird's activity and the cumulative sum of the liner activity, that no activity was being lost.

Food and water were supplied ad libitum. The initial transitional diet consisted of a mixture of chick-cracked corn and sunflower seed. Although this diet lacked many essential nutrients, it was readily accepted by the caged birds. Over a period of from four to seven days, a nutritionally complete diet consisting of a mixture of commercial poultry bits and crushed dry cat food was added in increasing percentages until these latter components made up nearly the entire diet. A commercial cage-bird multiple vitamin supplement was added to the food mixture. All food was radioassayed prior to use; activity levels were found to be $\leq$ 6fCi/g for the radionuclides used in these experiments.

Prior to the administration of any radionuclides, the birds were observed and weighed during the dietary transition period. Occasional birds which demonstrated a total failure to adapt to captivity either by severe and continuing weight loss or by violent and unceasing movement about the cage were released.

Lighting in the cage area was designed to duplicate the natural photoperiod. A modification to the flourescent lighting system described in the past reports was to add low-wattage incandescent lamps which were turned on one-half hour prior to the flourescents and which remained on one-half hour after the flourescents had gone off, thus simulating sunrise and sunset. Weekly corrections were made in timer settings to accomodate changing day length. Ambient temperatures approximated those outside, except that the minima were restricted to avoid freezing the water pipes in the cage room.

Radionuclides used in these studies were prepared from standard solutions diluted in physiological saline, buffered to approximate neutrality. Precise measurements were made of each dilution batch on NBS traceable counting systems. The solutions were filtered to minimize pathogenicity and sealed in sterile injection vials with rubber septa. All materials were kept refrigerated until use.

Administration of the material was made both orally and intravenously in order to establish absorbtion parameters. For the IV injections, either the jugular vein or, in the case of the Mourning Doves, the illiac vein of the wing was used. This procedural difference was necessitated when it was found that the jugular vein of the dove was too small to be used. Additionally, due to the poor muscular development and excessive fat concentrations in the Bobwhite obtained from the state game farm, the jugular was impossible to isolate and position for injection; thus on game-farm Bobwhite, only oral administrations were made.

Injections and/or oral administrations of any substance to living small birds is a difficult procedure. When the administered material is a radionuclide requiring prevention of loss and spillage to avoid contamination, the problems are compounded. For the IV injections, we found it necessary to employ carefully orchestrated procedures involving three people. Oral administrations were simpler, requiring only two people. All administrations were made using 1-cc disposable tuberculin syringes with 27-ga $\frac{1}{2}$" needles. Syringes were loaded from the sterile injection vials and the plunger pulled back until an air space was observed at the base of the syringe (needle hub area). The needle was then removed and discarded. A sealing cap was placed on the needle hub of the syringe and the syringe was measured in the laboratory's whole-body counters. After these measurements the cap was removed and a new, sterile needle was placed on the syringe. If the syringe was intended for an intravenous injection, the airspace was eliminated by depressing the plunger until a few drops of the radionuclide solution were ejected from the needle. These few drops were absorbed in a small sterile cotton wad in the bottom of the vial used to hold the syringe for measurements in the whole-body counters. After the injection, the syringe, the needle used for the injection, the syringe cap, and any swabs used during and after the injection were placed in the vial and remeasured in the counters. These procedures were designed to eliminate any possibility of radionuclide contamination on the external surfaces of the injection needle which might be deposited on the skin of the birds, and the pre- and post injection measurements of the injection apparatus gave a precise measurement of net injected activity.

For oral administrations, the same procedures were followed, except that there was no need to eliminate the air space in the syringe. In these cases, the bird's mouth was held open and the radionuclide solution dripped directly into the esophageal opening. Swallowing was induced in the rare instances when it did not occur voluntarily. After the completion of the radionuclide administration, about $\frac{1}{2}$cc of clear water was given in the same manner to ensure that the radionuclide was well washed down. No evidence of regurgitation was ever observed.

Doses, both oral and intravenous, were nominally 0.3 - 0.4cc, corresponding to an activity level of about 30 nCi. In the case of $^{131}I$ with its rapid rate of physical decay, those solutions were prepared such that the activity at the time of injection was in the 50 nCi range for the nominal dose volume. Maximum body burdens of $^{137}Cs$ and $^{131}I$ as observed in the wild in these species in our program have generally been < 0.2 nCi; thus, any pre-injection body burdens were less than 1% of the administered dose and were ignored in the subsequent calculations.

Calibration standards for the syringe measurements were (a) for $^{137}Cs$, a precisely measured amount of the stock solution in solidified agar contained in a vial with the same dimensions as the syringes, and (b) for $^{131}I$, also a precisely measured amount of the stock solution, but in this case, the material was adsorbed on activated charcoal contained in a similar vial, sealed with an epoxy plug. Calibration standards for the bird measurements were the uniform distribution phantoms which have been in use throughout the radioecology research program and which have been described in previous reports.

Birds were measured immediately after radionuclide administration for ten minute counts in each of the laboratory's two NaI(Tl) whole-body counters. Two counts were used to prevent possible loss of data in case of the malfunction of either system, especially during the period immediately following administration when rapid changes were expected to occur. Typical sensitivities for the better of the two systems is 0.02 nCi for a 100-g bird for a ten minute count, for either of the two nuclides used. The sensitivity of the second counting system under the same conditions is about 0.06 nCi.

During counting, the birds were held in the same manner as has been used throughout the project, i.e., in cylindrical Lucite restraint cages with paper liners. Only rarely did birds excrete during the counting process; when this occurred, the droppings were collected and measured separately. The birds were measured every three hours for the first twelve hours following administration, then at 24 hours post-administration. Successive measurements were made daily for the next six to ten days, and finally every two to three days, depending on the observed trend of the data. Although one bird was held for 125 days, most were released in about thirty days. Release was conditioned on (a) no detectable change in the slope of the elimination curve for a number of successive measurements, usually four, and (b) a total body burden of the administered radionuclide equal to less than ten times the observed average environmental burdens.

A few birds were sacrificed at various times after radionuclide administration. These birds were disected and their major body component groups were measured separately to determine the radionuclide distribution. In addition, a few of the caged females, especially the game-farm Bobwhite, laid eggs during their captivity. These eggs were collected and measured. A few of the eggs were separated into their three major components and measured separately.

A total of eighty-two individual birds were used for these studies. Seventy birds were used for the $^{137}Cs$ phase and twelve for the $^{131}I$. Due to a lack of time and funds, fewer $^{131}I$ administrations were performed than we had desired.

## $^{137}Cs$ Metabolism

Table 8 lists the details of species and administration modes employed in the cesium portion of the radionuclide metabolism study.

Table 8. Schedule of $^{137}Cs$ Administrations in Birds

| Species | No. by IV | No. by P.O. | Total |
|---|---|---|---|
| Blue Jay | 7 | 13 | 20 |
| Bobwhite | 6 | 13 | 19 |
| Mourning Dove | 11 | 8 | 19 |
| Red-winged Blackbird | 6 | 6 | 12 |
| Column Totals | 30 | 40 | 70 |

Approximately 30 nCi of $^{137}Cs$ activity carried in 0.4cc of physiological saline was administered to each bird in a single dose. Minimum post-administration holding time for the cesium group was ten days; the maximum was 125 days, and the mean was about thirty days.

At this writing we have been unable to discover a computer program to perform a multiple component exponential curve fitting routine by least-squares analysis which accepts, isolates and enumerates an unknown number of exponential components (>2) and includes in its output the necessary and essential error data. Many of the potential sources of such programs have indicated that accurate multi-component exponential fitting programs are clearly needed, but the need is as yet unfilled. We therefore present graphical displays of the radionuclide metabolism data. In Figures 21 through 28 , each sub-category of Table 8 (i.e., Blue Jay/IV, Blue Jay/P.O., etc.) is presented separately. Data are portrayed in terms of the percentage of original administered dose as a function of time after administration.

Examination of the figures will show that, with very few exceptions, the data are well grouped within each sub-category. Indeed, there does not appear to be any significant difference in the results for the two administration modes for any one species. The graphic data do not allow one to clearly deliniate any possible differentiation of the elimination curve into gut and tissue components by visual means. The fact that the initial rapid elimination of a major portion of the administered dose appears independent of the mode of administration is an especially interesting observation. Previous researchers (cf. Anderson, et al., 1976) have inferred that the observation of two-component elimination curves from birds under both acute and chronic oral administrations of radionuclides represented the classical gut and tissue components. However, our data which demonstrate very similar curves for both oral and IV administrations indicate that some unexplained physiological phenomenon is operating. Anderson (op. cit.) indicates that their Bobwhite after acute administration (birds fed tagged food for four hours) eliminated 48% of the dose within 48 hours. For our birds given a single oral administration of $^{137}Cs$, 58 ± 14.7% of the dose was eliminated in 48 hours. Elimination from our Bobwhite which were given $^{137}Cs$ intravenously was 60 ± 7.3% in the same time period. Further, a superposition of the IV and oral graphs for each species shows that there is no initial offset of the oral data which would be expected from an unabsorbed portion of the dose passing rapidly through the gastrointestinal tract and being excreted. These factors lead us to postulate essentially total absorption of the administered oral dose; any evidence of a multi-component elimination curve must be attributable to factors other than a gut versus tissue differentiation.

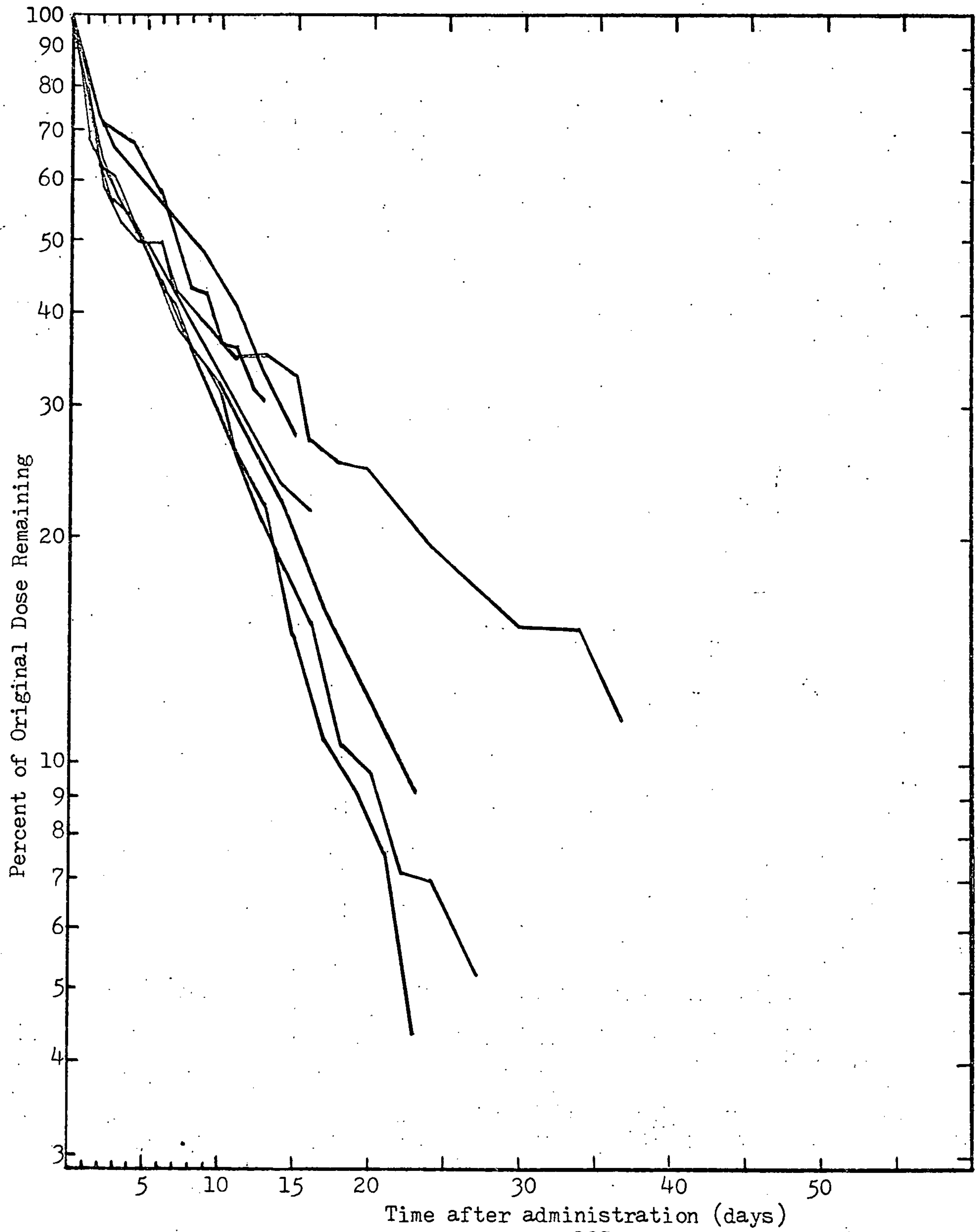



Figure 21. Intravenous administration of $^{137}Cs$ in Blue Jays.

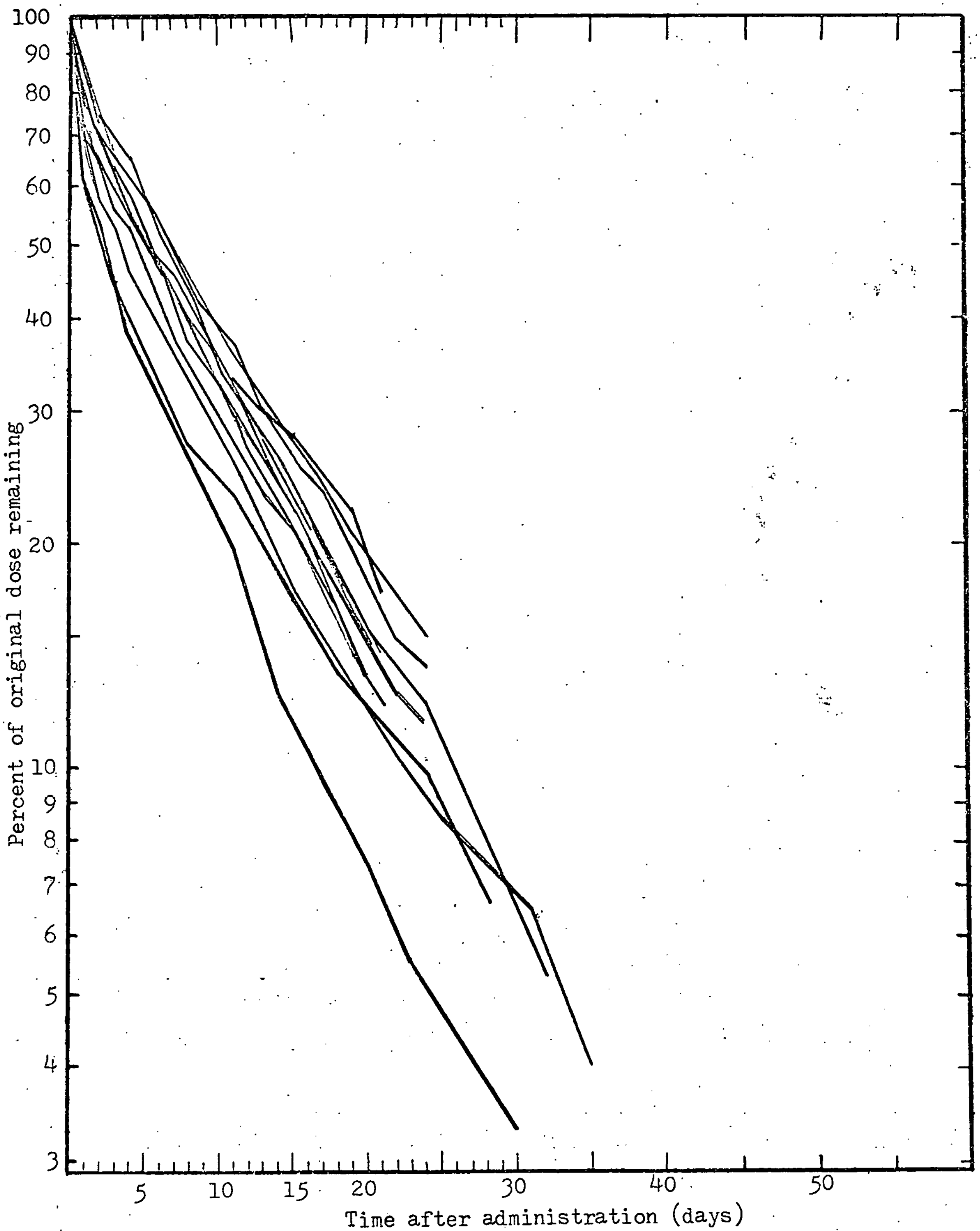



Figure 22. Oral administration of $^{137}Cs$ in Blue Jays.

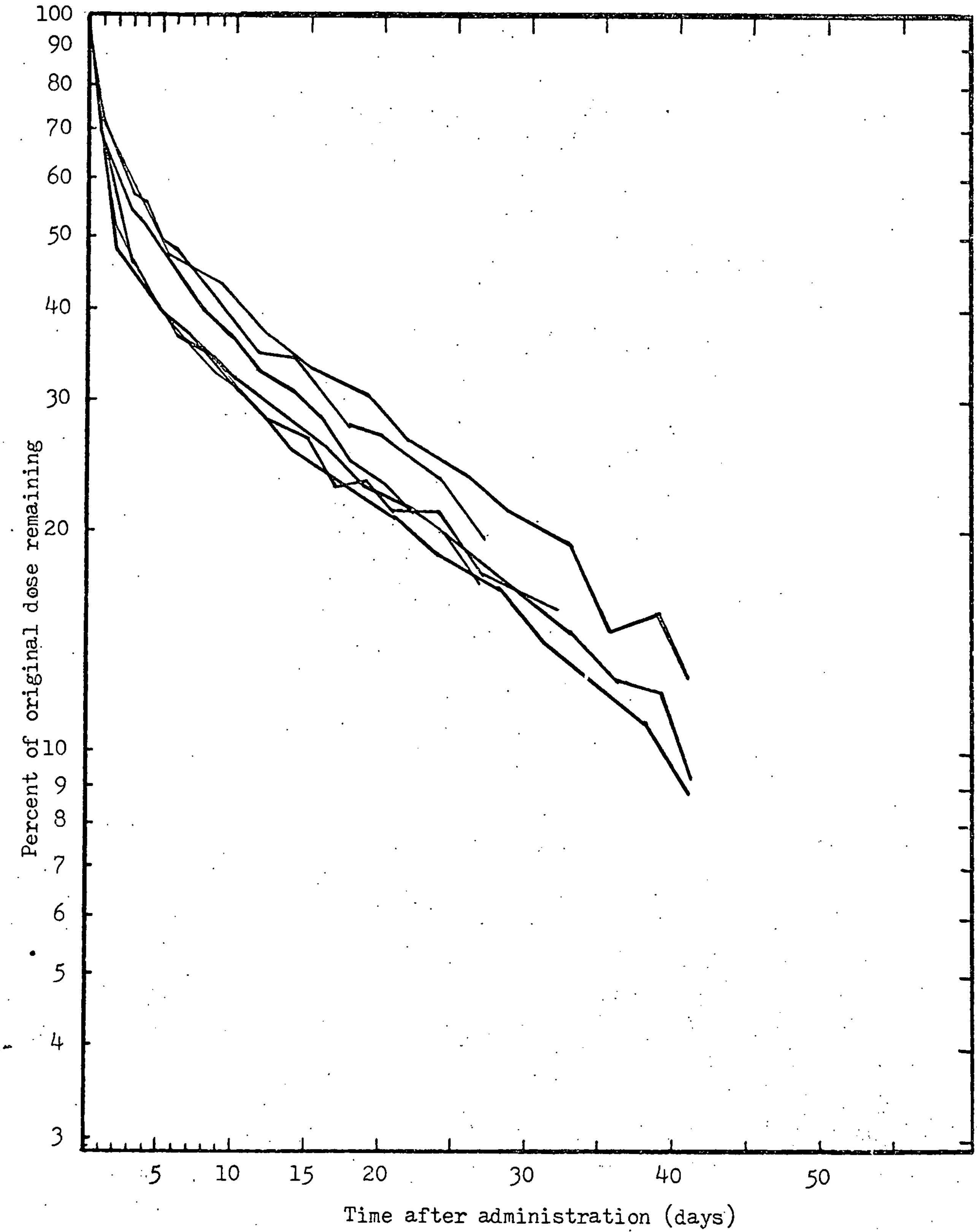



Figure 23. Intravenous administration of $^{137}Cs$ in Bobwhites.

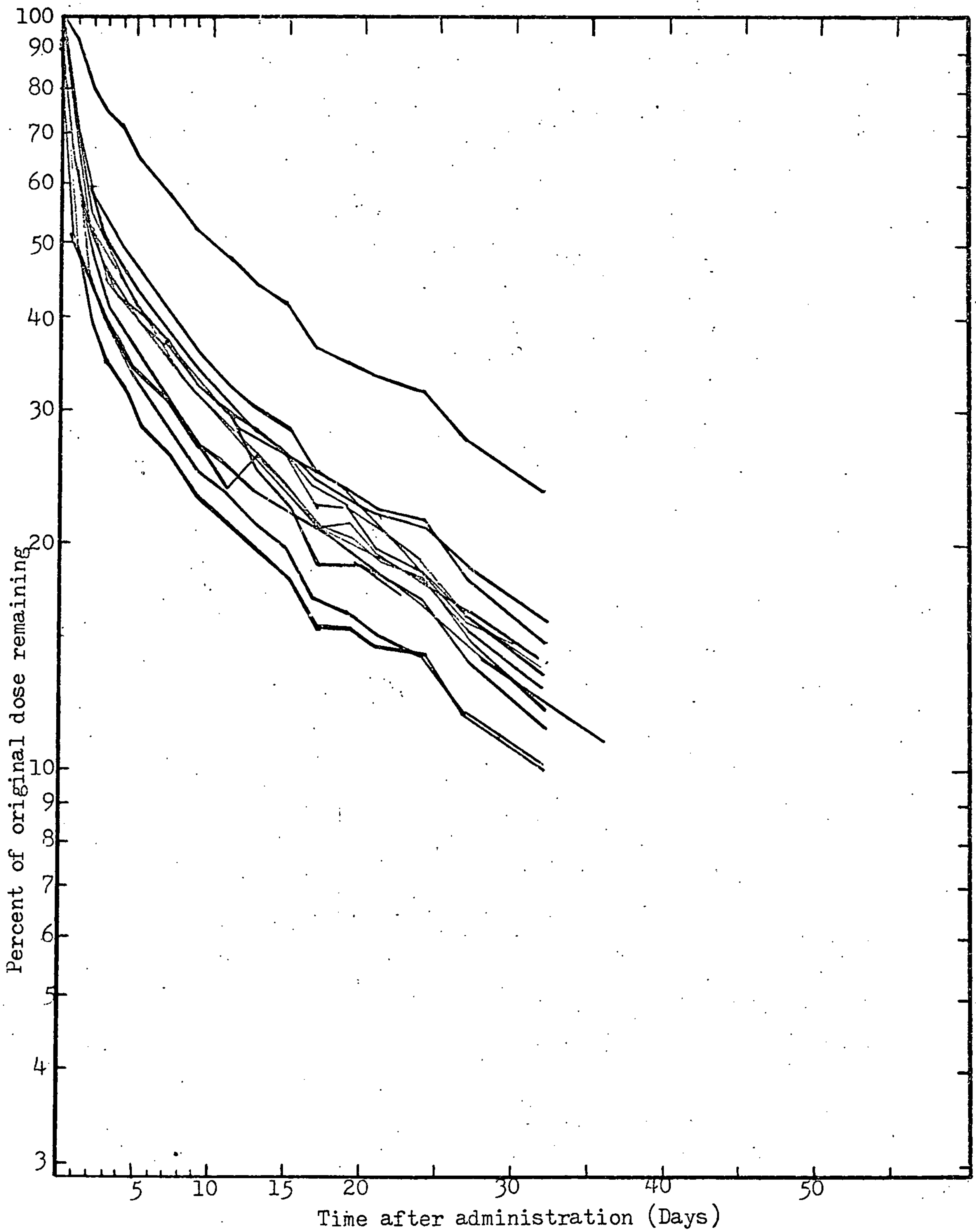



Figure 24. Oral administration of $^{137}Cs$ in Bobwhites.

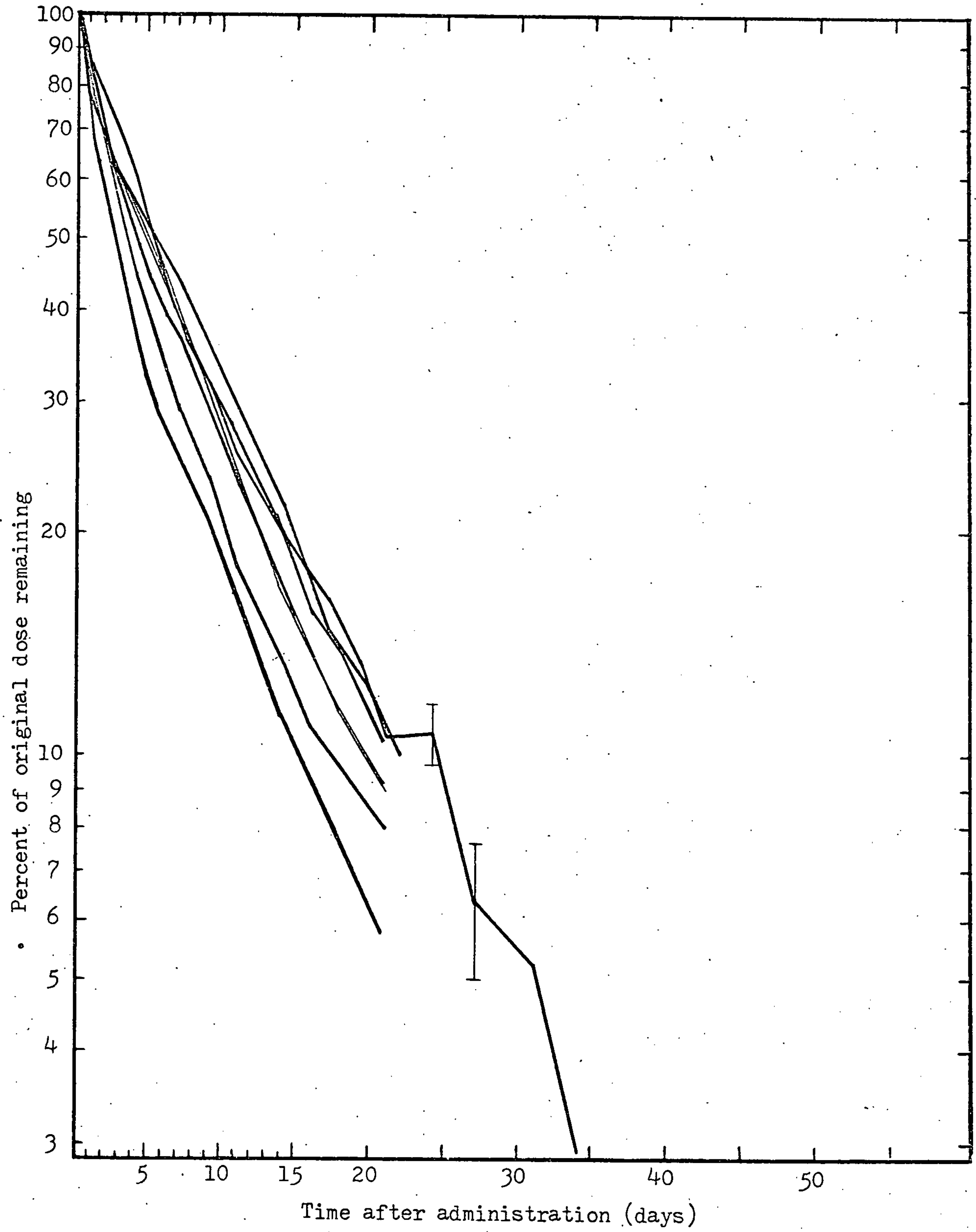



Figure 25. Intravenous administration of $^{137}Cs$ in Mourning Doves.

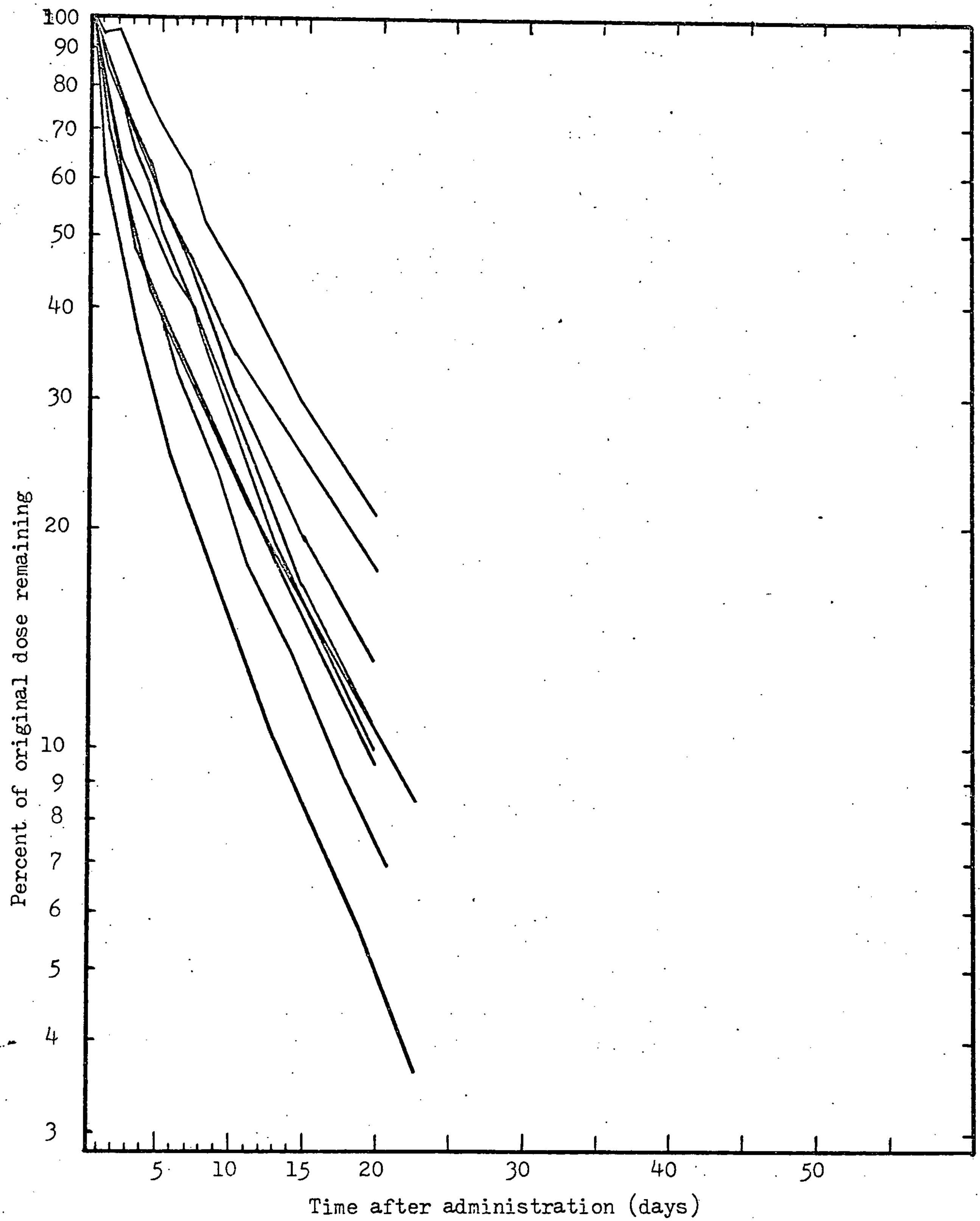



Figure 26. Oral administration of $^{137}Cs$ in Mourning Doves.

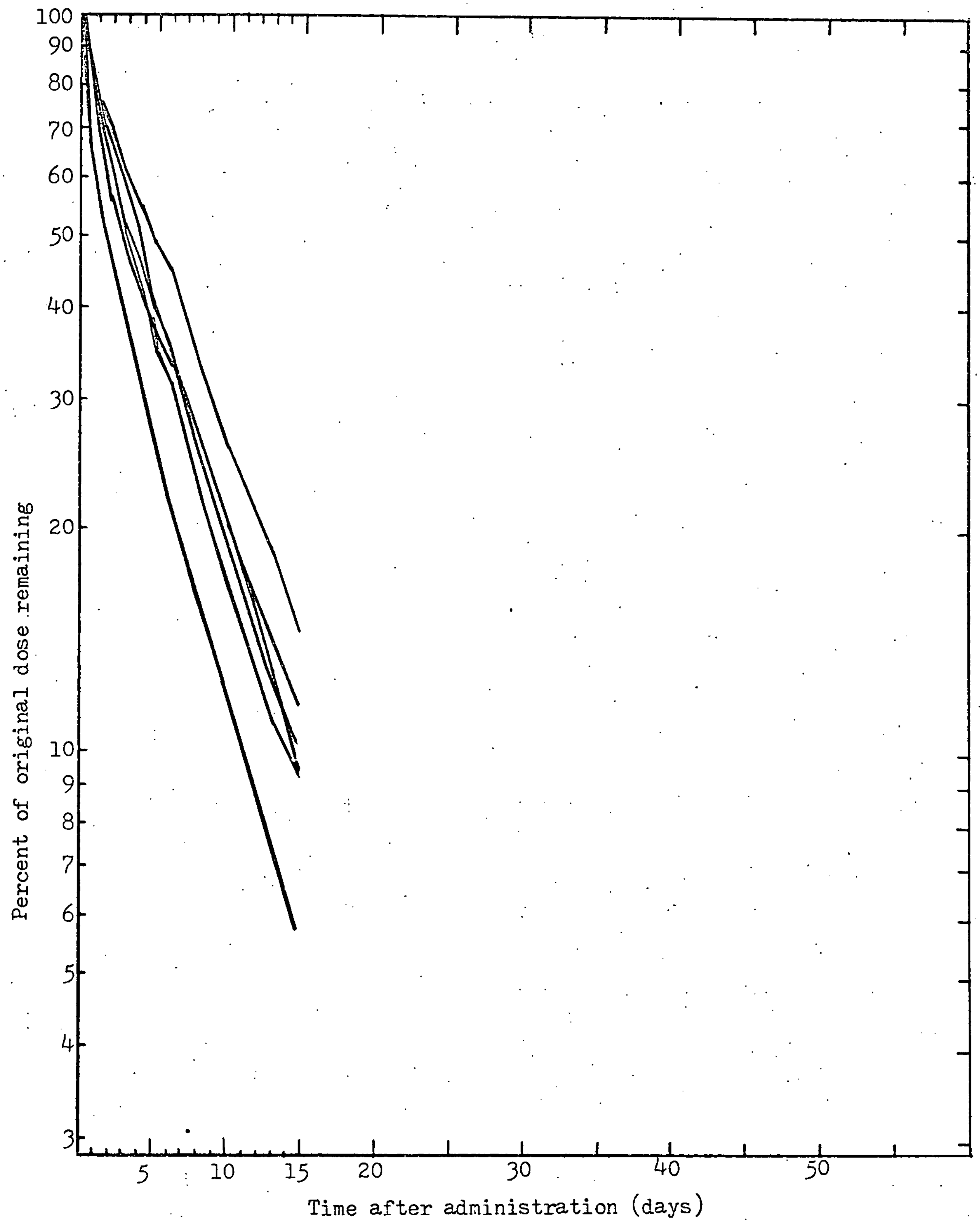



Figure 27. Intravenous administration of $^{137}Cs$ in Red-winged Blackbirds

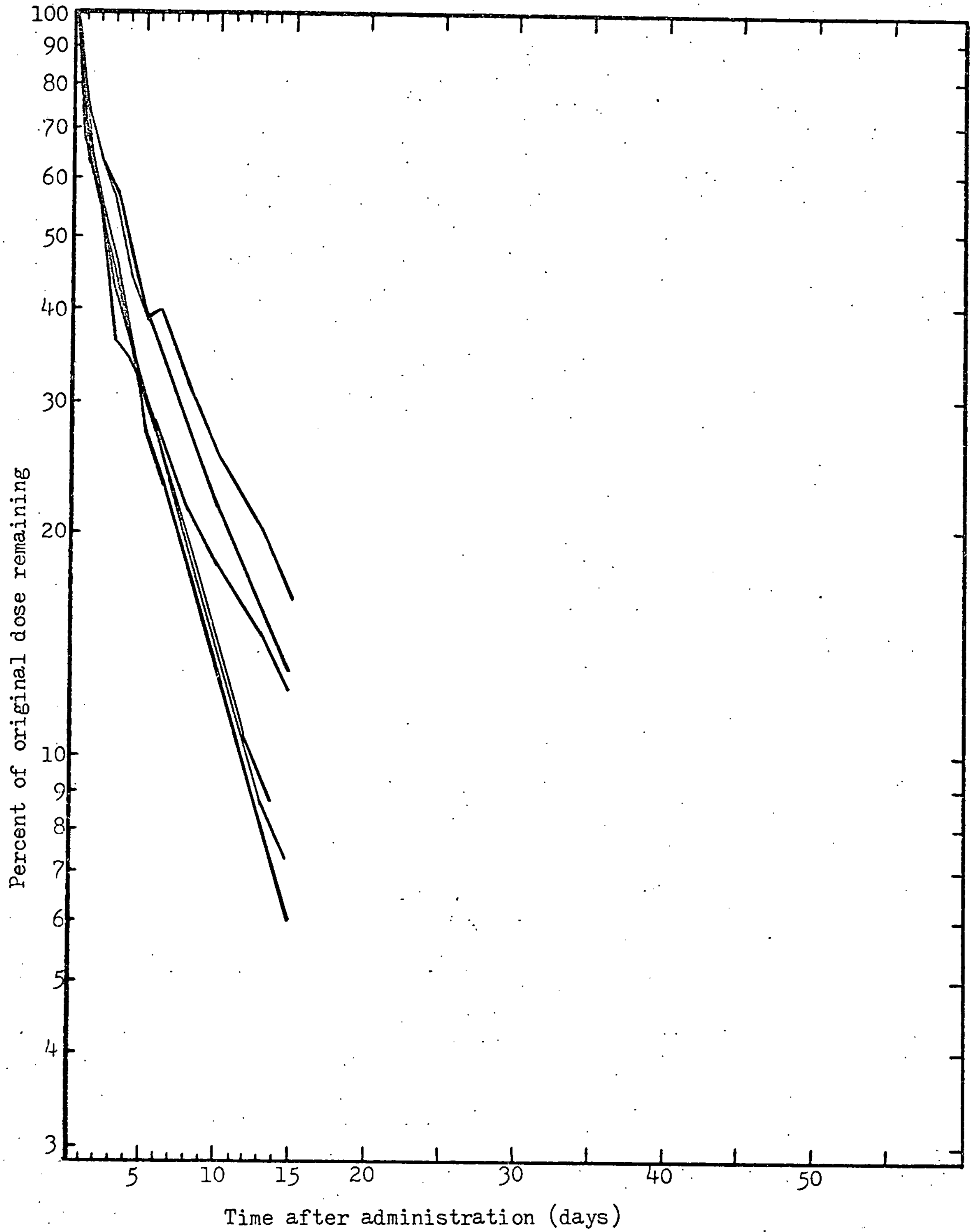



Figure 28. Oral administration of $^{137}Cs$ in Red-winged Blackbirds

At this juncture we are unable to see any evidence of a physiological basis for the markedly different $^{137}Cs$ levels demonstrated by the field data which so clearly divied these four species into two groups, the Mourning Dove and the Red-wing whose $^{137}Cs$ body burdens are nearly always below our system detection limits of 0.05pCi/g, and the Blue Jay/Bobwhite group whose mean $^{137}Cs$ burdens are in the 1 - 2 pCi/g range.

As with the iodine data to follow, the precise mathematical expression of the radionuclide metabolic rates must await our access to appropriate computer programs.

A number of birds were either collected or died naturally while in captivity. These birds were disected and their major body components were measured separately. The results of these measurements are given below in Table 9.

Most of the Bobwhite used in these studies were obtained from the game-bird hatchery operated by the Commonwealth of Massachusetts and were thus well adapted to captivity. Gravid females continued to lay eggs throughout their period of captivity. Since the Bobwhite is an indeterminate layer, daily removal of eggs from the cages ensured a continuing supply. These eggs were measured separately in the whole-body counters. The calculated activity was added to the sum of activity measured in the collected droppings, this sum being used as an independent check on the accuracy of the bird measurements by ensuring that the total of the bird's activity and the sum of the collected droppings equalled the originally administered dose.

After initial measurement, the eggs were placed in an open-mouthed plastic bag and boiled until hard, then separated into shell, white, and yolk, each of which was counted separately. All of the $^{137}Cs$ detected in the eggs was concentrated in or on the shell, and little or no activity was recorded from eggs laid more than five days after the radionuclide administration. Activity levels as high as 0.37nCi were recorded from eggs laid within 24 hours of administration, representing about 1% of the total dose. By comparison, during the same initial 24-hour period activity levels from collected droppings showed that as much as 70% of the administered dose was voided in the droppings.

Infrequently, a bird would excrete while in the counting chamber. This occasionally happened during the first of the two ten-minute counts

| Species | Time After Administration | Muscle | Skeleton | Skin & Feathers | GI Tract | Heart & Lungs | Liver | Kidney |
|---|---|---|---|---|---|---|---|---|
| | | Percent of Total Body Burden In: | | | | | | |
| Blue Jay | 6h | 31.2 | 24.0 | 2.1 | 26.5 | 6.6 | 7.5 | 2.0 |
| | 9h | 39.6 | 33.4 | 3.4 | 15.7 | 3.6 | 3.2 | 1.1 |
| | 3d | 33.8 | 26.1 | 13.2 | 11.6 | 7.1 | 5.5 | 2.6 |
| | 3d | 54.5 | 31.8 | 3.1 | 7.5 | 1.0 | 1.4 | 1.0 |
| | 28d | 43.4 | 30.4 | 8.7 | 8.7 | 2.9 | 2.9 | 2.9 |
| | 33d | 19.5 | 65.3 | 4.2 | 9.3 | 1.0 | 1.0 | 0 |
| | Wild Bird 1[1] | 50.0 | 25.0 | 0 | 0 | 0 | 25.0 | 0 |
| | Wild Bird 2[1] | 60.0 | 13.3 | 0 | 0 | 0 | 20.0 | 6.7 |
| Bobwhite | 40d | 51.7 | 12.7 | 31.3 | 0 | 1.7 | 0.8 | 1.7 |
| | 42d | 75.4 | 13.2 | 5.7 | 1.9 | 1.9 | 1.9 | 0 |
| | 42d | 74.7 | 19.6 | 2.8 | 0.9 | 0 | 0 | 1.8 |
| | 42d | 77.0 | 17.0 | 2.0 | 0 | 0 | 0 | (5.0)[2] |
| Mourning Dove | 6d | 43.8 | 27.8 | 7.8 | 15.1 | 1.5 | 2.4 | 1.6 |
| | 6d | 50.5 | 38.1 | 2.0 | 4.6 | 2.1 | 1.9 | 0.8 |
| | 7d | 44.3 | 31.4 | 7.7 | 11.8 | 1.8 | 2.0 | 0.8 |
| | 21d | 21.3 | 55.7 | 11.5 | 3.3 | 3.3 | 3.3 | 1.6 |
| | 28d | 43.4 | 30.4 | 8.7 | 8.7 | 2.9 | 2.9 | 2.9 |

Notes: 1. Wild birds, no laboratory radionuclide administration, taken for comparison.

2. This measurement is of fat bodies separated from the region of the breast muscle of an extremely fat bird. No kidney measurement for this bird.

Table 9. Summary of $^{137}Cs$ Distribution in Disected Specimens

immediately following radionuclide administration. The activity excreted during this immediate post-administration period, typically less than twelve minutes, usually amounted to one or two percent of the total dose, but in the case of one Blue Jay given $^{137}Cs$ intravenously, slightly more than 16% of the entire dose was excreted in less than fifteen minutes!

## $^{131}I$ Metabolism

Time and financial limitations precluded as full a program of $^{131}I$ metabolic studies as we had desired. Twelve birds were used in the iodine study, four Blue Jays, three Bobwhite, and five Mourning Doves. Since a careful review of the $^{137}Cs$ data showed no apparent difference in the results from oral and intravenous administrations, we elected to begin by using only oral administrations because of the greater ease and lessened chance for contamination with this method.

Because of the rapid physical decay of $^{131}I$, administered doses were on the order of 40 - 60 nCi per bird, or about a factor of 300 over our system detection limits, ensuring sufficient activity for an adequate measurement period.

Figures 29, 30, and 31 represent the $^{131}I$ metabolic data. As with the cesium data, the figures illustrate the percentage of the original dose remaining as a function of time after administration. In this case, appropriate corrections have been made for physical decay. Representing far fewer birds, these data are less well grouped than the cesium data, and the need for mathematical analysis is even more evident. It is clear however, that there is an extremely rapid initial turnover, with the Blue Jays, for example, voiding 85 - 95% of the original dose in one day or less. Our measurements made during the detection of reactor-released iodine reported in previous Technical Progress Reports corelate very well with these findings.

Because of the small number of birds involved in the iodine measurement program, no collections and associated disection analyses were made. The new group of quail included two females; fourteen eggs were obtained in as many days. The eggs from both females continued to show significant levels of iodine activity after ten days, with one egg on the tenth day

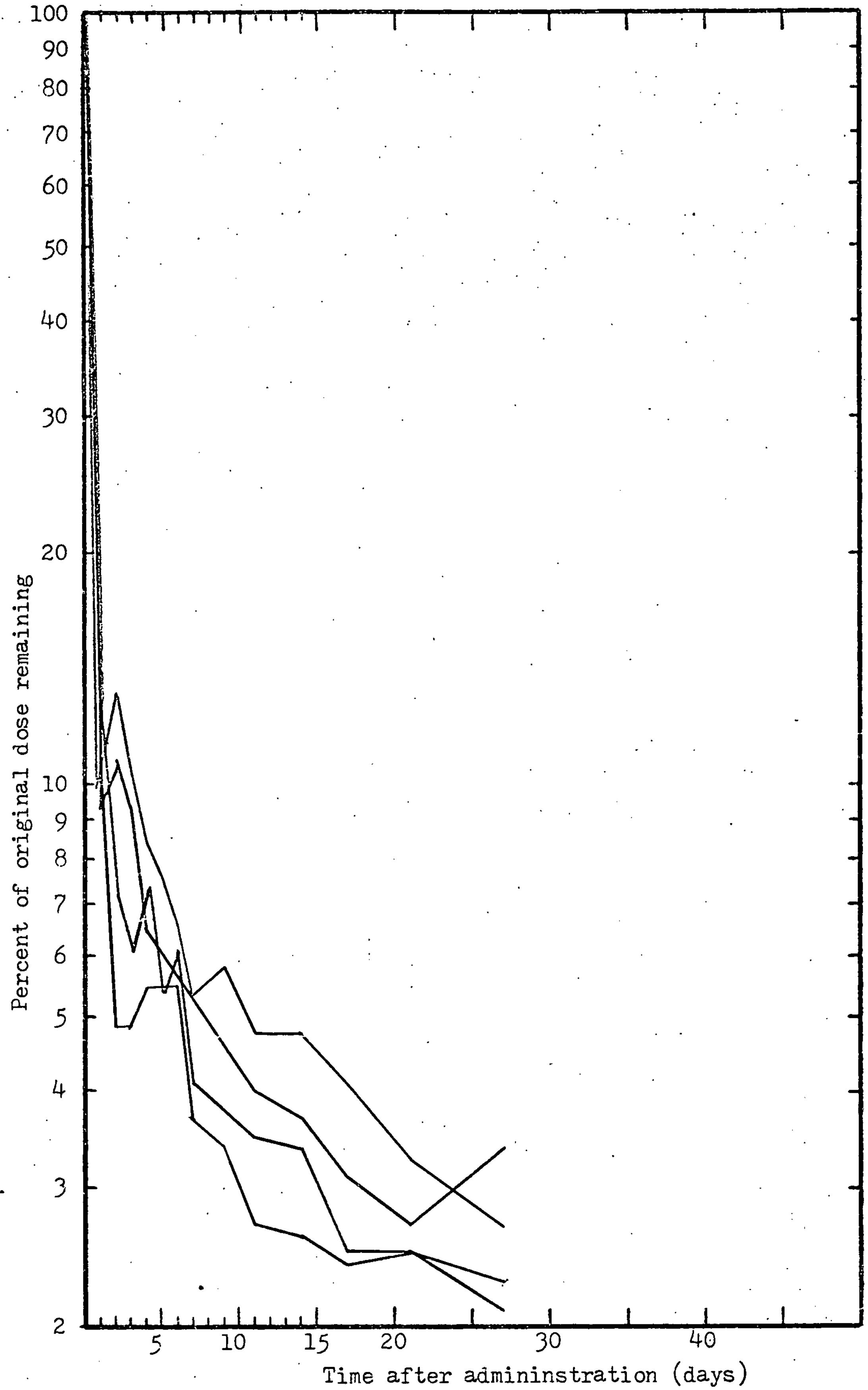



Figure 29. Oral administration of $^{131}$I in Blue Jays.

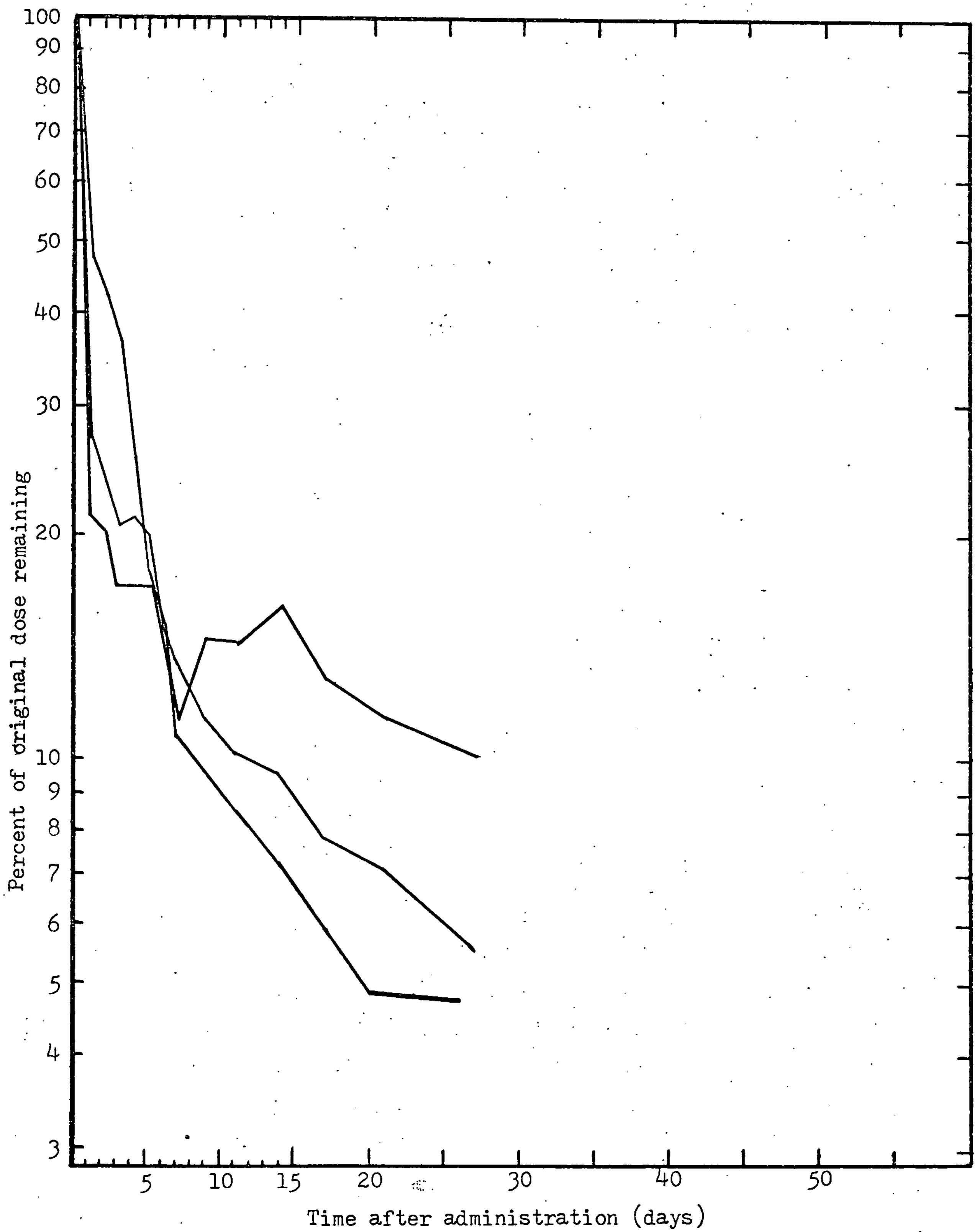



Figure 30. Oral administration of $^{131}I$ to Bobwhites.

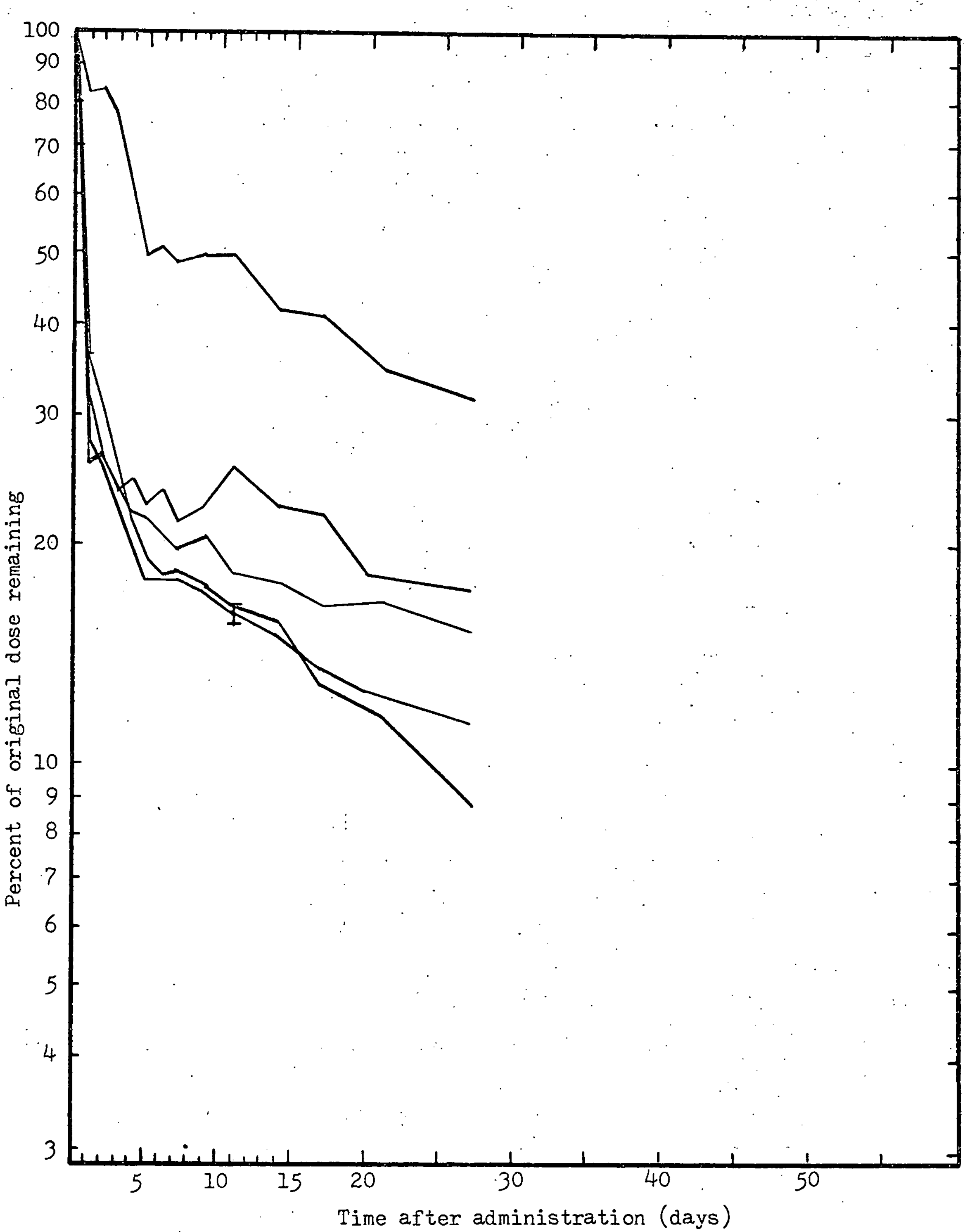



Figure 31. Oral administration of $^{131}I$ to Mourning Doves.

showing $^{131}I$ equal to nearly one half of the body burden remaining in the quail. Indeed it is evident that, in contrast to the experience with cesium, a significant fraction of the activity voided by the female Bobwhite was in the eggs. Also, in marked contrast to the cesium data, all of the $^{131}I$ activity of the eggs was concentrated in the yolk.

It is evident that much further study remains to satisfactorily describe the metabolic parameters of $^{131}I$ in these birds. We plan to carry out this study as a part of a program funded by a grant from the General Services Foundation which will allow the continuation of this research effort for one year.

V. Future Plans

A grant from the General Services Foundation will allow the continuation of the research program into avian radionuclide metabolism for one additional year. It is hoped that during this year we will be able to catalog the biological half-lives and absorbtion and retention data for a number of additional radionuclides which are expected to appear as reactor effluents.

VI. Time Commitment of Principal Investigator

The Principal Investigator spent ten to twelve percent of his time involved in the research funded under this contract during the period covered in this report (1 July, 1975 to 31 December, 1976).

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