Keep me in the Lab.

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PUERTO RICO NUCLEAR CENTER

THE RAIN FOREST PROJECT
ANNUAL REPORT FY - 65

Puerto Rico Nuclear Center

Rio Piedras, P. R.

The Rain Forest Project

Annual Report

March 1, 1965

Reports by Visiting Participants
Are Included as an Appendix

Howard T. Odum

Terrestrial Ecology Program I

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REPORTS OF PARTICIPANTS

A B S T R A C T

This is the annual report for work done on the rain forest project at El Verde, Puerto Rico. A year of pre-irradiation measurements, construction and installation of the source (10,000 Curies), and preparations of the area ended January 19, 1965 with the start of 90 days irradiation. An account is given of the measurements taken in the various phases of work by resident staff and visiting participants. Some scientific results are included. The annual pattern of biological processes involves some properties which are remarkably constant and some other patterns which have definite seasonal patterns.

INTRODUCTION

This is an annual progress report for the rain forest program at El Verde, Puerto Rico which has three objectives:

1. To determine the effects of gamma irradiation from 10,000 Curies of Cesium on a plot of lower-montane rain forest.

2. To measure cycles of fall-out elements in the rain forest system.

3. To determine the circuits of energy flow and metabolic processes of the ecosystem in order to understand the phenomena observed.

The project began in May, 1963, with various preparations of the irradiation and control areas such as trails, electric power, maps, towers, data cables, polar coordinate markers, instrument recording systems, and shelters. Work in the current year has concerned the regular measurement of some forest indices so as to document pre-irradiation properties. Many of these data have not yet been analyzed since the resident staff in the last 6 months has been largely involved in the logistics of getting the irradiation source installed and health physics aspects cleared. Ninety days of continuous irradiation began January 19, 1965 and continues as this account is written.

In last years proposal and report, the work was described in numbered phases, and for continuity this year's general account of progress is written with the same headings. Some scientific results follow including reports written by visiting participants. Submitted under separate cover is a proposal for work in the coming year. The proposed work involves repetition of the measures taken before irradiation plus work on cycling and metabolic objectives.

1. LOGISTICS

In the course of the year additional preparations were made of the study area, the El Verde Station, and facilities in Rio Piedras.

Electric Power

Until November, 1964, power was supplied by our paired diesel generators. A power line contract was arranged with the Water Resources Authority, the costs of clearing a mile strip charged to the project. After the station was rewired, power service was changed from generators ending 15 months of continuous service made possible by continuous trouble shooting by the resident scientist, Mr. Drewry. One of these generators remains as a standby for part of the station circuit. White power lines are now stretched on the ground through the forest study areas. For some needs involving critical voltage levels a gasoline generator station is provided in a shelter near the giant cylinder site. The power line to the tower is black, and 220 volt lines operating the source are red. Some of the lines have been in the forest for 2 years without failure as yet.

Cienega Alta House

Precipitated by the coming of Mr. Robert Ford Smith, former employee and now ORINS fellow at the University of Georgia, a special 5 year, no cost, lease was taken with the Institute of Tropical Forestry, U. S. Department of Agriculture, for one of the concrete forest houses, located at Cienega Alta about 5 miles further up Route 186 from El Verde Station in a spot of great beauty on the edge of the Luquillo forest. The house with around 900 square feet had propane facilities but no electricity other than some old wiring for generators. With some funds provided by Mr. Smith and matching funds from PRNC, the Water Resource Authority installed a power line to that house. One of our radiation guards (Moisés Parrilla), who is also an electrician, installed house wiring. This dwelling thus provides housing for the visiting program in addition to that at the El Verde Station.

Concrete Platforms

Prior to the moving in of the source Mr. Ramón Nieves and 3 crew members were brought in for several weeks. With materials carried in by the Youth Camp men and assisted by our regular staff, concrete foundations were poured for the Cesium Source, the towers of the giant cylinder, the 15 HP moter and 7 foot fan, and a larger pad 19 feet by 14 feet for Dr. Weinbren's field building for mosquito-catching operations between the rivers on the ox trail above the control center. This will next be supplied with a power line from the El Verde Station.

Inter-agency Agreement

After some delayed negotiations, the inter-agency agreement between the Department of Agriculture and the Atomic Energy Commission was finally signed providing the El Verde Station and 160 acres of Rain Forest for the research for a 5 year period. This arrangement puts radiation safety as responsibility of the AEC but provides for approvals by the Institute of Tropical Forestry on matters of construction and forest cutting.

New Laboratory Building at El Verde

After an appropriation of $20,000 from general plant project funds, preliminary plans and specifications for a small laboratory at the El Verde station were submitted. Based on this, AEC contract procedures for construction went into operation with final plans by the architectural firm, SagMag. After initial bidding, final negotiations provided a contract with Dot Corporation in Carolina with construction starting in November. The floor plan is given in Fig. 1. The building should be ready for occupancy by the end of radiation.

The new laboratory has air conditioning and de-humidification systems, some circuits which are voltage regulated, a hood, and an isotope storage and dilution room. The five main rooms are designated for five main functions: electronics, microscopic work, field tracer work, analytical work, and processing work for handling of botanical and soil samples. The present instrument room remains as control center and office-laboratory of resident scientist.

Station Modifications

A gas refrigerator was provided for Dr. Weinbren's program in the house middle section, a small refrigerator was provided for the northwest room, and a hot water heater was installed for the resident scientist's apartment. The visitor's room doubled as laboratories during the year. Further additions of wiring, voltage regulators, and racks were made to the instrument room which is shown in Fig. 2. The electronic bench was equipped with an oscilloscope and some frequency instruments. The interior of the station was painted.

Bridges

Murphy and others constructed a steel personnel bridge above the Sonadora River on the main trail from El Verde station to the study area to eliminate accidents crossing the rocks and isolation of personnel due to flash flooding. Across the two rivers on the ox trail above the uphill control center, steel treads were cabled to the rocks to provide firm footing in low and medium river stages there.

Crown Cable Car

To provide access to forest crowns, Mr. Robert Ford Smith, P. Murphy, Dr. Joe Edmisten, and others stretched a half inch steel cable 600 feet starting with a Tabanuco fork 90 feet high in the uphill control center and ending near the radiation center. A shorter 3/8 cable was also passed in the crown of the lower center. Cable positions are drawn in Fig. 2 of Smith's report below.

Mechanically Damaged Control Area

Related to Mr. Smith's dissertation problem, a third area was laid out for later mechanical damage so that succession may be compared with that in the irradiated area. The forest was opened mechanically so that the optical properties at the ground correspond to those in the irradiation area. This area is located on a ridge downhill to the north and is marked with concrete posts.

Rio Piedras Laboratories

The project room in the basement of Institute of Tropical Forestry was the center of the grinding, weighing, and processing of forest samples, the metabolic studies on seedlings, and microscopic work.

Following construction of a wall partition, a laboratory in the Biomedical Building with hood was assigned to the project. Ashing, chlorophyll, and counting are now centered there.

Administrative matters, secretarial functions and communication centralization remained in the office at the Biomedical Building where some new files were added.

Mrs. Ana Josefina Correa developed procedures, reports, files, and office level accounting as Administrative Assistant.

2. PLANTS

Vegetation and Topography Maps

The collaboration with the Tropical Terrain Research Detachment of the U.S. Army Corps of Engineers Waterways Experiment Station under Mr. William Rushing continued during the year by which data and methods are shared due to common objectives in analyzing vegetation. Very important to the project are three sets of maps in which each tree, major rocks, stumps, logs and half meter contours in the 30 meter radius circle are plotted by transit. Accompanying data on height, diameter, and other aspects are tabulated. These maps total 10 sheets and can serve as the basis for the dosimetry maps, the prism chemical calculations, etc. These maps will be first reported through Army publication outlets.

Seedling Drawings

Dr. James Duke of the Department of Agriculture in Beltsville, Md. made two trips to Puerto Rico to identify and characterize vegetation in some herbicide studies not far from El Verde. Common to that project and the El

Verde project was the need for identification of seedlings. Mrs. Peggy Duke, botanical illustrator, was brought down by PRNC and Mr. Alejo Estrada Pinto was assigned to help locate the seedlings in the rain forest area and in other communities as well. The result is a manuscript with 36 plates, which has already been submitted for publication.

Dr. Duke has helped members of the project with taxonomic problems and allowed some of his unpublished reports on vegetation in Puerto Rico to be mimeographed for project use.

To aid our participants a listing of new and old names is included as Smith's Table 6. Another aid was the publication of the book guide to trees by Little and Wadsworth, obtainable from the Superintendent of Documents for $4.25.

Tree Data on Punch Cards

Continuiing the liason with the Tropical Terrain Research Detachment, PRNC set up a punch card machine and operator at Stop 7 1/2 to put the data collected by the Army group in the mapping study on IBM cards to meet their objectives as well as ours. These cards have now been punched according to the format given as Fig. 3. They went to the Mayaguez computer center for various computations such as means, frequencies, basal areas,volumes, etc.

Tree Trunk Growth Measurements

Peter Murphy continued his study of tree growth of 5 species with the guidance of Dr. Wadsworth. There is now a year's record with some of the data summarized in an appendix section. When it was suspected that the early measurements were too small due to tightening of tapes in the first months after installation, additional tapes were added to some of the trees with old tapes in order to get a correction factor.

Phenological Record

The record of fruit and flowers has now covered a year with data indicated in the data section.

Palm Populations

Progress on the study of palm populations is given in the report from Dr. Frank McCormick.

Limb Tip Growth

Begun by Mr. Murphy and continued by Mr. Smith, limb tips along the car cable were marked with metal clips so that the distance from clip to branch tip could be measured before and after irradiation. These trees have no annual limb scars. It was during this work that Mr. Smith fell injuring back and ankle.

Forest Biomass

The vegetation maps by Mr. Rushing and the Tropical Terrain Research Detachment permit prism computations of mass in more detail than was formerly contemplated. This work is yet to be done.

Roots and Microrhiza

Dr. Joe Edmisten made a working trip to explore relations of the soil and roots as reported in his report in the Results Section that follows.

Fungi

Dr. Cowley, University of South Carolina, and Mr. James T. Holler came in the summer for study of some fungal aspects. Mr. Holler remained making plate counts and isolations for his Master's thesis. Dr. Cowley also made a survey of some higher macroscopic fungi. Their report is included in the scientific results section.

Microbiological Processes

Dr. Martin Whitcamp, Ecology Division, Oak Ridge National Laboratory, came in December for some microbiological explorations as indicated in the report of his trip.

Algae

Dr. Phil Halicki visited for studies of algae, marked 50 stations, and arranged for the study of palm frond replacements for computing leaf succession.

Mosses

Dr. William C. Steere assisted by Mrs. Steere came from the New York Botanical Garden for a pre-irradiation study of the mosses as indicated in his report that follows in the next section.

Leaves on Shrubs

Following Mr. Smith's accident, Mrs. Smith aided by Juan Martínez completed some counts of leaf numbers on understory vegetation in the radiation area.

Chlorophyll

With leaves collected from numbered trees by Mr. Murphy, Marta De Arce and Carmen Laura Pereles made 850 chlorophyll determinations to characterize photosynthetic function before irradiation for comparison afterwards. Some summary of these data is given in the results section. A manuscript on chlorophyll work done in 1957-1958 by Odum, Abbott, Selander, Golley, and Wilson was prepared for publication.

Forest Cross Section

Using the forest cable-car cable as a transect, Mr. Smith made a forest cross section as indicated in his report in the results section.

Seedling Plots

Mr. Smith counted surviving seedlings a year after he marked quadrats in 1963.

Actinomycetes

Dr. Andrew Maretzki collected some samples of leaf litter and soil for Dr. J. J. Perry, Dept. of Bacteriology, N.C. State, Raleigh who made some surveys for actinomycetes.

3. WEATHER RECORDS

Solar Radiation Measurements

The Eppley instruments from U.S. Army of Natick have been recording for over a year with a few interruptions. When the hurricane was forecast to pass near San Juan, as promised, we pulled down the main tower and removed the top platform. Mr. Drewry made some calibration checks at that time and found some faulty flaking in one pyrheliometer. The full daylight photometer at a different time developed water leak. Both went back to Eppley Co. for rebuilding and recalibration. The photometer is back in service and the double hemisphere pyheliometers continue their records. A representative from the U. S. Army at Natick visited the project to observe our use of their instruments and other matters.

Forest Optical Density and Sunflecks

One ring of silicon cells has provided a years record of optical density. In November, George E. Drewry began recording on three other rings of solar cells including irradiation and control centers. Mr. Rushing reports a successful years use of the portable device developed for their plots through collaborative effort. A publication note is planned on this instrument.

Rainfall, Wind, Temperature, Humidity

The pre-irradiation annual record for the main tower above and below the canopy is mostly complete for rainfall, wind, temperature, and humidity. The Cup anemometer was out of function for part of the period, and there was some drifting in calibration of humidity and hot wire anemometer records. Additional thermistors were added in December.

The problems of catching malfunctions, inking, and dating charts was taken over by Mrs. Smith on a part time arrangement which involves a morning instrument routine. So far three of the Rustraks and Rustrak amplifiers have had to go for factory repair, a better service record than expected considering that many have been snapping away continuously for 14 months! As yet the weather data have not been analyzed.

Digital System

A Non-linear Systems 20 Channel Digital Scanner was purchased and Mr. Bill Moore and Mr. George E. Drewry began wiring the connections for the digital voltmeter, the word, and the scanning program. A program board was also purchased for an IBM 46 tape to card converter and is being wired with the aid of the IBM Service Bureau. The digital system is to go into operation when the new laboratory is ready. The system will give some data regularly routed to cards in addition to the roll charts. Mrs. Elpidia Rivera began punching temperature chart data on IBM Cards (Fig. 3).

5. CYTOLOGY

Dr. Francis Koo, at PRNC Mayaguez listed as half time on the project assisted by Mrs. Edith Robles de Irizarry in the laboratory and Mr. Robert Venator in the field, completed measurements of nuclear volume, made a study of radiation effect on bromeliads using a radiation source in Mayaguez, and explored some aspects of germination and meristems. To appraise the effect of radiation on the bromeliads, chlorophyll extractions were made and the sepctrophotometric measurements done in Rio Piedras by Marta De Arce along with determinations being made from the site. Dr. Koo's report is given in the Results Section.

Walking Sticks

Dr. Niilo Virkki collaborating from the Experiment Station made cytological preparations of testes of walking stick insects as material permitted. Mr. Phil Sollins during the summer collected animals for him. Phase microscopic equipment was ordered to replace equipment he has on temporary loan for this work.

Ferns

Dr. V. Sorsa and wife, both cytologists, enroute to Finland made cytological collections of the ferns.

6. ANIMAL POPULATIONS

Snails

Dr. Harold Heatwole, Department of Biology, UPR continued the population study of the large snails with assistance of part time students paid from the project at various times: Joaquín Molinari, William R. Bhajan, Emilia Matos, and Zaida Miranda. His report is attached.

Amphibians and Lizards

The population study of the coqui frog and two dominant species of Anolis lizards was continued by Dr. Fred Turner and Mr. Clayton Gist of the Radiation Laboratory at UCLA. Dr. Turner came on working trips and Mr. Gist and family moved down for the year being attached administratively to PRNC. Salaries and scientific direction remained through UCLA, special local expenses and travel were budgeted through the project budget. Mr. Gist returned home in November. Dr. Turner visited in December with Mr. Rowland to put micro-dosimeters in frogs and lizards. Their report follows in Results. They presented some of the data at meetings in September.

Birds

Dr. Harry Recher made quarterly working trips to census the bird populations, plotting position maps, computing densities, recording aspects of phenology. His report is included in results.

Frog Noise

Mr. Drewry reports on his annual record of Coqui sound in the Results Section. He has also made progress in circuits for recording other population components.

Insect Diversity on Sticky Paper

Mr. Drewry took over the sticky-paper sampling with the aid of Joaquin Molinari and Eusebio Díaz Pagán. This work involved computing species diversities, setting up keys and reference collections for the 500 species, sending specimens off for identification, and making some tests of substrate effect.

Herbivore Action on Leaves

Assisted by Marta De Arce, Peter Murphy and others continued the leaf hole study begun by E. P. Odum. Samples from the leaf fall were placed in the light box and the percent of holes determined by reading first with leaves only and then with leaf holes obscured with pieces of aluminum foil. An annual record is given in the Results Section.

Bromeliad Fauna

Dr. Bassett Maguire, The University of Texas, provided results on his working trip in the Results Section.

Mammals, Mosquitoes, Virus

These populations are studied under a different project under Dr. Paul Weinbren which is funded and administered through the PRNC Biomedical Division, and submits a separate report.

Soil Microzoa

Some results on this phase are given by Dr. Richard Wiegert from his working trip from the Institute of Radiation Ecology of University of Georgia at Aiken, S. C.

7. METABOLIC STUDIES

Seedling Study of Shade and Sun Species

As his Master's Thesis at UPR Ariel Lugo completed measurements of photosynthesis versus light and air flow velocity for two species, whose seedlings are sun-adapted and successional and two dominant climax species whose seedlings remain for long periods in deep shade and grow when the canopy opens. Some of these data are given in his report in the Results Section.

Shade Mircrocosms

Fourteen plastic dessicators with seeded soil and plants remained unattended at the future irradiation site for a year. The small hose fittings remained opened for gas exchange. Prior to irradiation all were opened, excess water which had accumulated was drained out and the systems matched according to general quantities of vegetation. Seven were placed in the irradiation center and seven in the control center.

Diurnal carbon-dioxide curves were previously made after months of acclimation by removing the microcosm temporarily to an air-conditioned room and a fluorescent light providing similar conditions of light intensity and temperature to that of acclimation. An example is given in the Results Section.

Soil Metabolism

As shown in last years progress report the soil metabolism is highly sensitive to flow rate during its measurement. When some visiting participants repeated some measurements using our hot-wire anemometer box previously described, they obtained values ten times those we obtained previously. The principal innovation they added was a foam rubber seal to the soil rather than allowing inflow of air under the edge of the box. There may have been suction created because inflow holes were not large enough. Thus further study of this must follow.

Giant Cylinder Experiment

About 50 meters from the irradiation center, construction of the giant cylinder began in late Fall. Six small aluminum towers were carried into the forest by Youth Camp men and set on concrete pads with guys to the trees. The towers were connected to each other by cables to form a hexagon 60 feet across so that no guys were needed on the inside. The forest at this point is 60 feet high. Ariel Lugo, Alejo Estrada Pinto, and others gradually raised the crank-up towers, using small cables to tie back branches so as to make a framework for/cylinder with space for a plastic curtain. With aid of a group of seamstresses from El Verde, 10 mil polyethylene was sewed on a wire ring and suspended from the hexagonal tower frames by 12 nylon draw ropes working through pulleys at about 50 feet. The plastic was readily hauled up as a curtain to about 40 feet, but beyond that the increasing weight began to create strains resulting in plastic tears, broken struts in the aluminum towers, and other problems. The plastic was then cut at ground level and a second plastic curtain sewed so that the weight could be distributed from two heights without the necessity of hanging all the weight from one ring.

With the help of AEC Engineer Mr. Keller, the giant fan and 15 HP gasoline moter was installed on the concrete pad. With the plastic at 40 feet, a smoke bomb was cleared from the cylinder in less than 5 minutes. The 7 foot fan at present is geared for relatively few rpm, 200 maximum, and does not use the full power of the engine. The engine exhausts directed into the outflow of the fan were carried downwind well away from the cylinder and did not feed back into the cylinder as determined in a preliminary measurement with the infra-red analyzer. The scheduled radiation date caught up with this second priority phase so that it must be completed after April when the area is again accessible. A photograph of the cylinder with the plastic at about 25 feet is given as Fig. 4.

Transpiration

With one of the Hygrodynamic Humidity Systems already built into the regular weather, recording from the tower, a second portable system was tested by Mrs. L. Ortíz as a means for measuring transpiration in open flow systems through plant leaf chambers. Although more sluggish than the CO_2 analyzer, there is less noise in the record. Whether we will be successful in scaling this up to the giant cylinder in order to get forest transpiration remains to be seen.

8. PHOTOGRAPHIC RECORD

Many pictures were taken during the year and are part of the general record. One series will be published as a pictorial record. Any picture is available by duplication for any participant in connection with his special reporting and publication. Visiting participants contribute copies of pictures they take to this pool.

Helicopter Series

Continuing collaboration with the Tropical Terrain Research Detachment of the U.S. Corps of Engineers Waterways Experiment Station, the Cold Regions Research Laboratory of the U. S. Army at Hanover, New Hampshire, and the Department of Agriculture herbicide project of the Experiment Station at Mayaguez, a helicopter flight was chartered every other month,and Mr. Dave Atwood took pictures with color, infra-red, and camouflage film.

Dr. Phil Johnson of the Army group at Hanover is making a study of the optical density of the films and relating it to ground measures such as optical density of the forest.

Light Plane Series

Peter Murphy of the PRNC staff obtained his pilots license and with the help of Clayton Gist, Robert Ford Smith, and others began taking aerial pictures in alternate months from a chartered light plane.

Tower Series

Mr. Clayton Gist took a number of pictures of the radiation center at various times from the top of the instrument tower which overlooks the radiation area.

Pipe Series

Mr. A. Atwood and Dr. Johnson continued their in-forest record of pictures from reproducible positions on fixed pipes.

Oak Ridge Photographer

A pictorial record of forest activity at the time of source installation was made by E. Westcott AEC photographer on a visit from Oak Ridge.

Animal Series

A series of pictures of representative animals was taken by Mr. Clayton Gist of UCLA.

9. DOWNWARD FLOWS

Annual Litter Fall

Peter Murphy, Alejo Estrada, and Doroteo Martínez collected leaf fall monthly from the 50 stations set up by Dr. Wiegert. After the leaf hole measurements were made, the litter was oven dried. Fruits were separated, identified by Alejo Estrada, and dried separately. See the Results Section.

Litterbag Decomposition

The field experiments of leaf decomposition in fiber-glass bags set up by Dr. Wiegert and some later series set up Peter Murphy were continued with bags removed for drying and weighing at 4 month intervals.

10. CESIUM SOURCE AND PROTECTION

Manufacture and Installation of the Source

A response to the call for bids came from 5 firms; the purchase order for the design and construction of the source went to the low bidder, American Nuclear Corporation of Oak Ridge, Tenn. for $21,444. Following part I of the procedures set up in the purchase order, plans were drawn and subjected to criticism within PRNC and then included with slight modification in a Hazards Report concerning the entire aspect of source installation, operation, and matters of Health Physics and public safety. When this document was approved by the AEC in Oak Ridge, Part II of the purchase order, the actual construction, went into effect. As provided in the order, inspections of the apparatus were made in Oak Ridge in November by Odum, C. S. Shoup, Joe Lehnhardt and H. Haeker from AEC Operations in Oak Ridge, and A. Jones, engineer invited from ORNL. A series of modifications were recommended and incorporated at that time.

The source was shipped by truck and boat arriving at San Juan harbor Dec. 3. After inspections by PRNC Health Physics officer's, Dr. Ferrer Monge and Pedro Cruz, and the Coast Guard responsible for the harbor, the source was loaded on truck and driven with preceding and following vehicles to the end of the Sonadora Road 600 feet from irradiation center. The helicopter team of the Puerto Rico Power Authority was enlisted and on the following Monday the source-pig, weighing one ton, was picked from the truck by a 90 feet, 1/2 inch, steel cable and within 15 minutes was set down on the concrete pad in the forest by precision flying and ground radio guidance. The blast of the helicopter broke many limbs in the radiation center changing optical properties somewhat.

Six red wires for power and control were stretched from El Verde Station to the source site, passing on separated insulators in the very high radiation field near the source.

A 400 foot, 3/4 inch conduit was laid over the irregular ground contours and threaded with a 1/16 inch stainless steel safety cable that operates an emergency mechanical trip hook.

A two inch steel tube tripod was placed over the source with feet in concrete so as to deflect any falling tree.

George Drewry built an additional safety provision, a half inch steel cable loop about 15 feet above the source for helicopter snatch of the source. The source apparatus although cabled to a 6000 pound concrete pad, is released from these three connections by mechanical cable trips that open when stainless steel trigger wires are drawn as the steel snatch loop is lifted. Thus, should all other devices fail, the source could be withdrawn by helicopter and carried to a deep pool of water of the river for repair operations. Five feet of water would provide the same protection as the five inches of lead. Helicopter personnel would be partly shielded by the plug.

Mr. J. H. Wilde, predident of American Nuclear Corporation, the manufacturer, came for 4 days during the final installations making various checks and recommendations. The shipping cover was removed, the hoist machinery was bolted in its place, and the various cables were attached. Fig. 5 was taken at that time. The control box was installed in the instrument room at the El Verde Station 2000 feet from the source along with safety devices. Then after fences were finally completed and two amendments to the Hazards Report were approved by the AEC area office, an official inspection and radiation test was held January 12. Dr. Roig represented the Director's office, Mr. Pedro Cruz the Health Physics Division, and Mr. Keller the AEC Area Office.

The first up-source test, Jan. 12, was made satisfactorily and while the source was up, Cruz, Odum, and Vallecillo surveyed the fences and peripheral areas with 4 suvey meters with the result given in Fig. 6 and 7. The radiation levels were less than those previously given in proposals for the work.

The down source mechanism also worked. After raising the source again, scram and mechanical trip devices were tried, with no response.

The source was lowered with the down mechanism and various inspections made which showed too much friction in the mechanical cable in the conduit and in the electrical hoist devices and fluid brake.

After a phone conference with American Nuclear Corporation, the mechanical cable was removed from conduit to the free air, #10 oil was placed in the fluid brake, and bearing friction was reduced. An electric anti-moisture heater was reduced in power and moved so that it was not vaporizing lubricating fluids. The counter weight on the trip cable was reduced. A new authorization memorandum was processed, and a second test was made January 18. All systems were functional at that time. When some under-fence holes were sealed, Dr. Bugher made a personal inspection, and final irradiation began the evening of Januray 19. A scram test made a week later showed systems still functional.

A partial plan for the source is given as Fig. 8 and the electrical system as Fig. 9. The microswitch that turns the red "source-out of box" lights on is located on the side of the vertical tube and is actuated as the plug passes. Two other microswitches are in the moter box on either end of the hoist spool so that the completion of the turns up or the completion of the turns down actuates a switch, cuts off the moter automatically, and extinguishes the moter light. If there is power failure, a relay is tripped so that when power is restored, no power passes beyond the control box without active turn of the power key.

Either power interruption or turning the scram switch down, releases the magnetic clutch so that the 45 pound plug with source unrolls the free running hoist cable from the drum, the plug reaching the pig in 3 seconds. Bringing the source down by moter operation of the down button takes 14 seconds. The up button brings the source up to full height in 19 seconds.

Source Operation

Source operation is made by an approved check list to help avoid omission of important steps. There is a metal box that contains the key to the up-source button. A bar on the box, something like the one at Brookhaven and Emory, has provision for many locks to be added including one by the official operator. During periods in which the source is down and someone is authorized to go within the 160 meter fence, he puts his lock on that box-bar so that it cannot be raised until he returns and removes it.

Up source procedures require verification of written authority, 5 minutes of siren, removal of locks, test of the time required for light change in the up process, relocking of the up button, and locking key in the box.

The scram button is available to anyone who might suspect that someone unauthorized was beyond our controlled areas. After scramming, the one responsible operator is required to raise it again.

That radiation is on may be determined by (a) the radiation recorder in the instrument room whose transducer in 300 feet from the center, (b) by using a survey meter at the control house (0.1 mr.per hr. when up and less than 0.01 mr. per hr. when down), by the red lights on the panel board, and by the audio crackle over the phone from the tower shed ratemeter. After the source is put down, the power is turned off if persons are to enter the 160 meter circle. The responsible operator is the first person to go in with the duty to check that there is a firm seat of source with survey meter.

If work is to continue for longer than two days, the source plug is also unhooked from the hoist apparaturs, and the electric power turned on so that the heater is operating.

Safety Fence and Signs

The provisions for source operation, safety, and health physics are covered in detail in the Hazards and Safety Report and its two amendments now approved. As shown in Fig. 6 there is a 160 meter hog fence 8 feet high stapled from tree to tree. Holes underneath where gaps are created by rocks and ground gaps are closed with fence patches. At 25 feet intervals are signs with the inscription.

Extreme Danger
High Intensity Radiation
Beyond this fence Do Not Enter

Area Extremadamente Peligrosa
Radiación Intensa
No Pase Mas Allá de Esta Verja

These signs are masonite and in red and yellow warning colors.

At approximately 500 meters on the downhill side of the mountain towards people a single strand of barbwire has been stretched at 3 feet and the same warning sign placed at 25 feet intervals. Where this wire approaches a forest trail it changes into fencing with signs. In the sector on the north side which is nearest to the Route 186 Bridge over the Sonadora River where people sometimes picnic, the line becomes a fence for 600 feet. As shown in Fig. 6 a gate was put across the Sonadora Road with combination lock.

Guards

Starting Dec. 4 with the assistance of the Department of Agriculture and the El Verde Ranger and Mr. Josué A. Colón of the administrative division, 4 guards were employed from the village of El Verde. The patrol routine set up involves an 8 hour shift with watch clock stations at the Ranger Station, the El Verde station, the Sonadora gate, and Smith's house. The patrol has four functions. 1. By patrolling road access, keep survillance of persons who are in the vicinity to prevent anyone from going beyond our outer warning line. Parenthetically, it should be mentioned that one has to do some rough climbing and get muddy and messy to get that far. 2. Guards require any persons working at the El Verde station or in the zone between the fences to have written pass and film badge. 3. Guards check the control panel and watch for power failure and other malfunction. 4. Guards provide a personnel transportation shuttle to El Verde village and the Cienega Alta house.

Radiation Field

When the source is down, maximum radiation at the source is on the top side, 4 mr/hr. When the source is up, radiation at the 160 meter inner fence ranges 3 to 17 mr/hr depending on topography. At the 500 meter warning line of signs radiation is 0.1 to 0.3mr/hr. At the public road 186 the readings are less than 0.02 mr/hr including the points of "direct line of sight" and the Sonadora Bridge. At the El Verde station outside of the concrete buildings the radiation is 0.12 mr/hr. At the end of the mechanical trip cable within the inner fence but behind a ridge, the radiation is 10 mr/hr. A preliminary graph of dosage rate is given as Fig. 7. One survey was made by Mr. P. Cruz and Mr. F. Vallecillo; another was made by a team of about thirty members of U.S. Department of Agriculture Soil Conservation Service under Mr. W. E. McKinzie as a field exercise February 23, 1965.

Dosimeters

1000 sealed capsules from Con-Rad Company were placed within the irradiation field by Dr. Frank McCormick assisted by W. Rushing and associates so as to show micro-variations as well as provide a dosimetry map. Some of the 500 microdosimeters which are to be read by Germshausen, Edgerton and Grier were paired with the larger capsules and some were placed in a series along the cable-car cable. 180 microdosimeters were put in frogs and lizards, by Turner and Rowland, 50 in snails by Heatwole, and some in rats by Weinbren and associates.

Cobalt Survey

Prior to submission of the Hazards Report, Pedro Cruz and the Health Physics division brought a 5 Curie Cobalt source from Mayaguez, placing it at the end of the Sonadora Road. Air and forest penetration were measured to show that there were no features of the El Verde situation that might cause radiation to be more penetrating than at Brookhaven and at Georgia.

Film Badges

Starting with the arrival of the source in the area in December, a film-badge rack was set up at El Verde station and incorporated in the regular routine at PRNC by Miss Heidi Pabón of Health Physics. Also maintained were temporary film badge packs for the various workmen of Dot Corporation, visitors, etc.

Public Relations Briefing

As part of the necessary aspects of Health and Safety, a public information program has been conducted. First Dr. Bugher issued an announcement about the project in the newspapers in 1963. Then when the source was shipped from Oak Ridge, a news release there was picked up and repeated in several San Juan papers in November. At the time of source arrival, Mr. Trent of the AEC Operations Office took charge of public relations with several meetings held to make plans. Mr. E. Stockely Public relations officer from Oak Ridge came down and held several consultations evolving a written plan for the public relations announcement. According to that plan a simple announcement was issued in early December that appeared in all the papers and in one TV outlet. Then, when the fences and other preparations were in readiness, a formal public relations hearing under AEC control and auspieces was scheduled and organized by Mr. Rushford on January 8. Talks made by Mr. Floyd P. Trent, Dr. Wadsworth, Dr. Amador Cobas, and Dr. Howard T. Odum were followed by a trip in a chartered bus to El Verde. All attendants walked up the trails, examined the source, and observed various aspects of the study. Mr. Rushford distributed folders with large photographs taken by the AEC photographer from Oak Ridge, and sandwiches and coffees was served. The meeting was attended by various representatives of the press, Commonwealth Government, the Mayor of Rio Grande which is the nearest municipality to the site, and representatives of the neighboring Girls Scout Camp and Youth Camp. The briefing was followed by articles in the newspapers that week and some feature articles somewhat later. In spite of all the explanations and documents given the press, one article showed the source picture and described it as a new powerful dosimeter for civil defense surveys in the island. Most papers did carry the principal message that there was no danger whatever outside the fences, but there was dangerous radiation within. There have apparently been no editorial comments or public discussions of these announcements. A radical university student group included a paragraph in a mimeographed leaflet denouncing the project.

11. SYSTEM CHEMISTRY

For the most part radiation effect studies have taken precedent this year over chemical cycles studies. This emphasis will change after completion of the main radiation experiment, the completion of the El Verde Laboratory, and the arrival of a staff member to increase this work.

Chemical Composition of a Forest Prism

Mrs. George Ann Briscoe spent much of her time before leaving for England preparing 960 powdered samples of roots, limbs, trunk-woods, and leaves from 40 selected species. After chemical analysis, one may multiply the weights of each material by the analysis of that material and sum to get the chemical composition of the forest prisms. The detailed tree maps provided by Mr. Rushing's Army group will be the basis for that.

In collaboration with Dr. J. D. Ovington who had earlier visited and began these phases, the samples went to the Monks Wood Experimental Station, Huntingdon, England for analyses of principal common elements by the chemical section there.

Some soil samples are also being processed through a chemical section of the University of Georgia by Dr. Joe Edmisten.

Cesium and Manganese Peaks in Gamma Spectra

Taking a personal hand, Dr. Bugher assisted by Ada Livia Rodríguez de Colón and Marta De Arce made 60 gamma spectra of forest materials. In initial exploratory measurements strong cesium and manganese peaks were found in all leaf matetrials. With a year lapsed since the cessation of main atmosphereic nuclear testing, the leaves showed lower beta counts than we reported in last years study and the gamma spectra were simpler.

As a test of radiation effect from the Cesium Source on the ability of the forest to hold in cycle the cesium and manganese, effort was concentrated on getting measurements of the two elements from numbered trees in the radiation field before irradiation. Ash samples were prepared from new sun leaves, old sun leaves, new shade leaves, and old shade leaves of the 6 species being studied for growth. These measurements will be repeated on the same trees after irradiation. Some data are given in the Results Section.

Conductivity of Forest Fluids

A conductivity indicator was set up for remote recording of rain on top the tower and that falling through the forest. The conductivity was exceedingly variable from 10 to over 100 micro-mhos from rain to rain. Often more salinity was found in the electrodes under the forest, possibly due to recycling nutrients. The preliminary exploratory measurements show that some micro-habitat differences can be found. For example, the flow along trunks can be compared. Data will have to be corrected for the influence of the mobile hydrogen ion by taking concurrent pH measurements.

Resins

Some exploratory tests were made of salt uptake in resin tubes that were placed in the rain guage tubes. With the small water flows involved, the method was not sensitive enough to give good gamma spectra after 2 months. Some larger funnels will be required as is normally involved with this work. Dr. V. T. Bowen, Woods Hole Oceanographic Institute visited and was sent one set of resins for study with some sensitive counting equipment he is using. Depending on this result we can plan our rain studies in connection with next years water balance effort.

12. MEASURES OF TOTAL SYSTEM

No further efforts have been made this year in syntheses of data into circuit structures, electrical analogs, energy diagrams, and measures of organization because of the urgent pressures involved with starting irradiation and for lack of some key data now being obtained in other phases as already described.

13. PUBLICATION

Although a number of publications came out during the year by staff on work done elsewhere, no project work was published during the year and most writing awaits the post-irradiation comparisons.

The post irradiation studies will begin approximately May 1, 1965 with the first emphasis to be a year of measurements duplicating those of the pre-irradiation year. Hence, many data on the first objectives will be obtained by May 1966. Recently there has been consierable discussion of possible ways of reporting the project in the regular scientific literature. There now seems to be a consensus among many participants and staff that publication of a group of papers in one volume may be desirable.

Although the nature of the outlet is not yet determined, it may be wise to give everyone adequate notice that manuscripts of a combined volume of papers will be assembled in summer of 1966, which is a little over a year from now. A supplementary volume might follow several years thereafter with reports of the long range effects of the irradiation and emphases on the mineral cycling studies.

RESULTS

Annual pattern were measured by the various intrumental records, spot surveys and monthly samples of the pre-irradiated forest. Although many of the data are not analyzed for reporting yet, some properties of the year can be given in the following paragraphs and in some reports of participants that follow. Unquestionably, the El Verde forest plot is one of the most stable biological systems on earth, but there were definite seasons in the activity of particular species of plants and animals. Pulses of activity occurred in some processes that were continuous. Some reproduction phenomena were distinctly seasonal. The time dimension was separating functions, simplifying the life of the forest.

Leaf Fall

The leaffall at the 50 stations set up by Dr. R. Wiegert is reported in Fig. 10. The record confirmed the increased fall in the spring which had been qualitatively observed. With the exception of Buchenavia and one or two other species, new leaves were formed before others were dropped, so that the forest was continuously evergreen as previously reported.

Phenological Patterns

Some phenological patterns are given in Murphy's report. Some other data are given in Fig. 10 and 11. The graph in Fig. 10 shows the reproduction on 20 palms selected by McCormick and Murphy and examined monthly by various staff. Euterpe is one of the most abundant plants and its flowering and fruiting continued through the year but with a pulse with summer seedling swarm resulting. Bar graphs follow for some other species based on notes made each month by Alejo Estrada Pinto and others. In general the flowering was recorded for shorter periods than the fruiting which was extended throughout the year for many species, but not all.

Gamma Spectra from Fallout

The relatively high levels of fallout-radioactivity observed in leaves in 1963 declined during 1964-65 as might be expected with diminished atmospheric testing. A gamma spectrum of leaves from 1963 is compared with more recent spectra of similar leaf materials in Fig. 13. The later spectrum is simpler since the peaks of shorter lived elements declined leaving mainly those of potassium 40, manganese 54, and Cesium 137. Also shown in Fig. 13 and 14 are spectra of various forest phases and species. Although there are quantitative differences, spectra for the leaves of various species have about the same general appearance, and there is as much difference between leaves of different age on the same tree as between different species. However, the strong peaks in the gamma spectra for leaves and leaf litter were not in other components of the forest such as inorganic soil, roots, boles, limbs, and lizards.

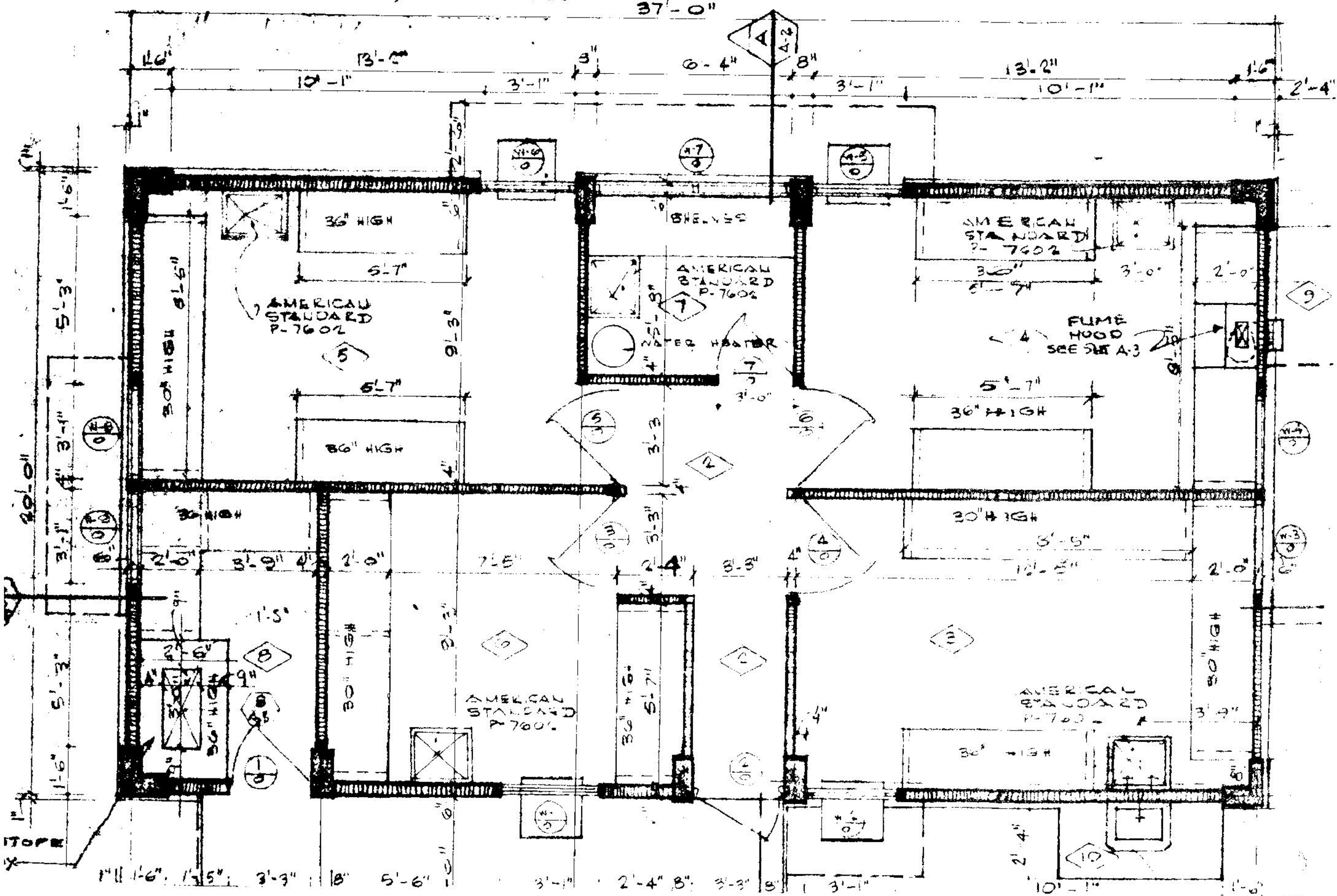
Gamma Spectra from the Cesium Source

Assisted by Bill Moore, Dr. J. C. Bugher carried the Gamma spectrometer to the El Verde Station instrument room placing the 2 inch scintillator crystal outside the window. The station is about 1600 feet from the cesium source, and survey meters show 0.13 mr per hour. The spectra which were found first with the source down (shielded) and second with the source up are given in Fig. 15. It is interesting to compare the background spectrum with the leaf spectra of Fig. 13 and 14. With the source up, one finds that almost all of the radiation which left the source at about 0.66 MEV had been transformed to much lower energies with the peak at 0.08 MEV.

Early Report on the Radiation Effects

As this report is being mimeographed, some radiation effects are being observed. The area around the center was examined several times since start of irradiation during short interruptions. A zone of dead brown leaves is spreading outward as graphed in Fig. 16. Patches of yellowing leaves may be detected further out as also graphed.

Fig. I New Laboratory at El Verde



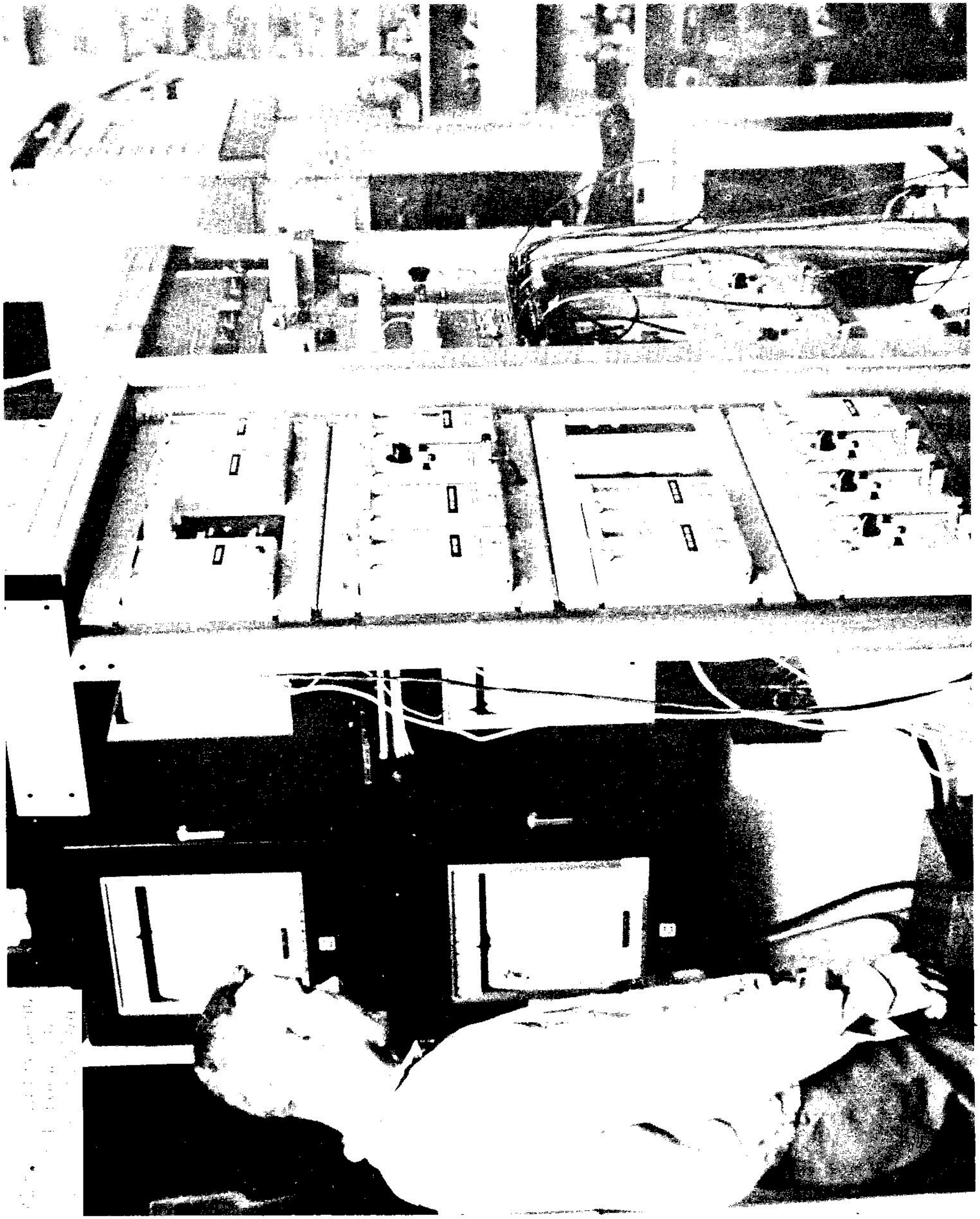
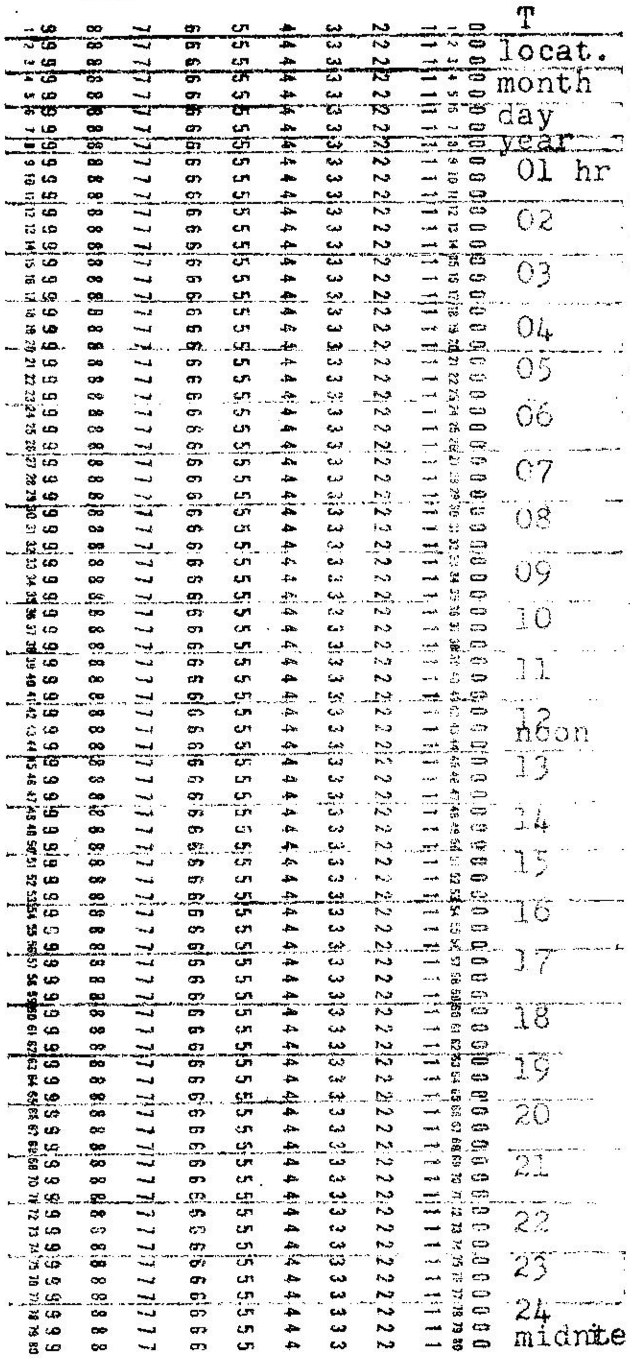


Fig. 3.

Format used to punch temperature data from Rustrak chart records Degrees Centigrade & tenths



Format of Tropical Terrain Detachment, Waterways Experiment Station used in vegetation study of the two circles out to 30 meters radius at El Verde.

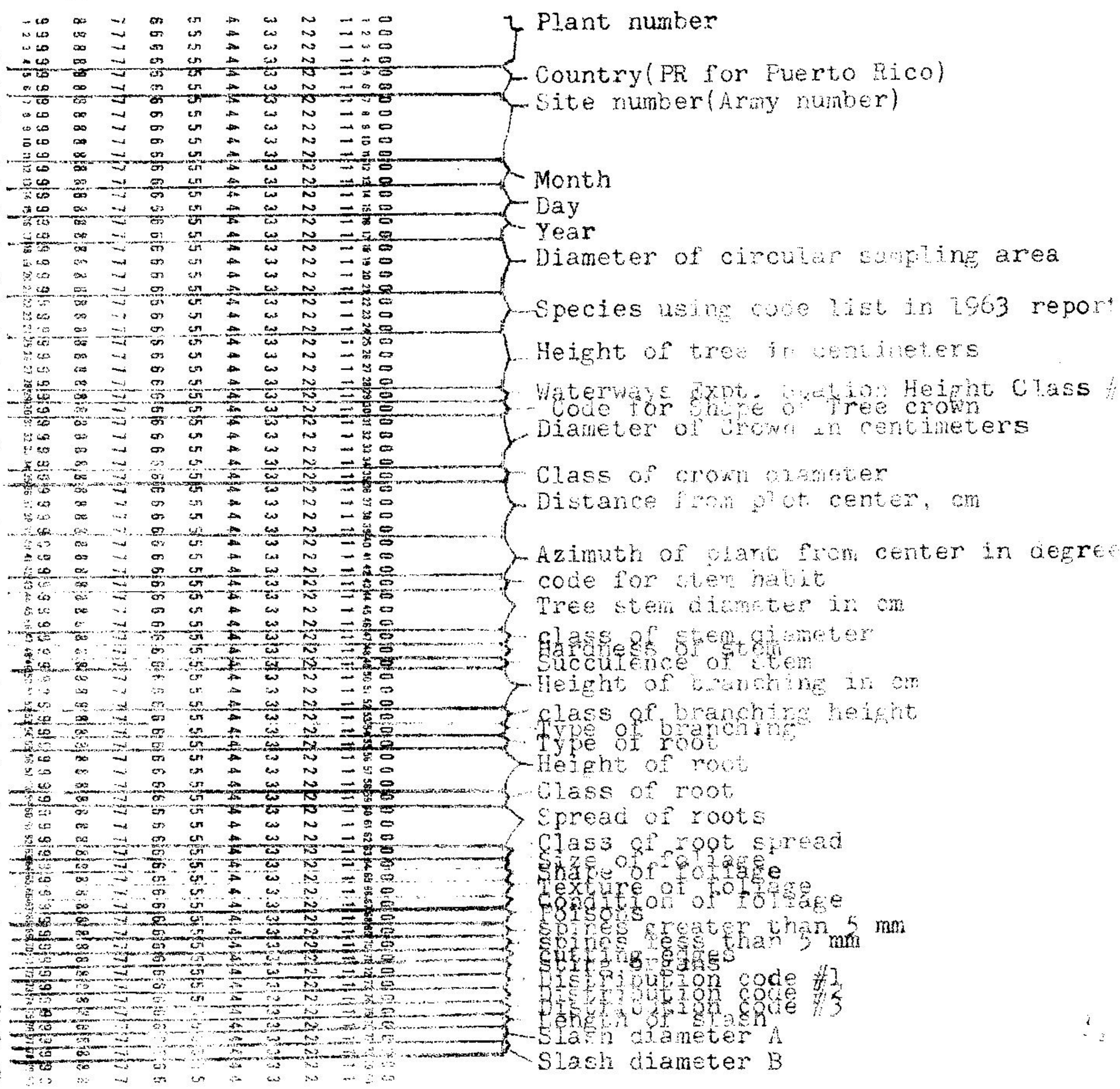
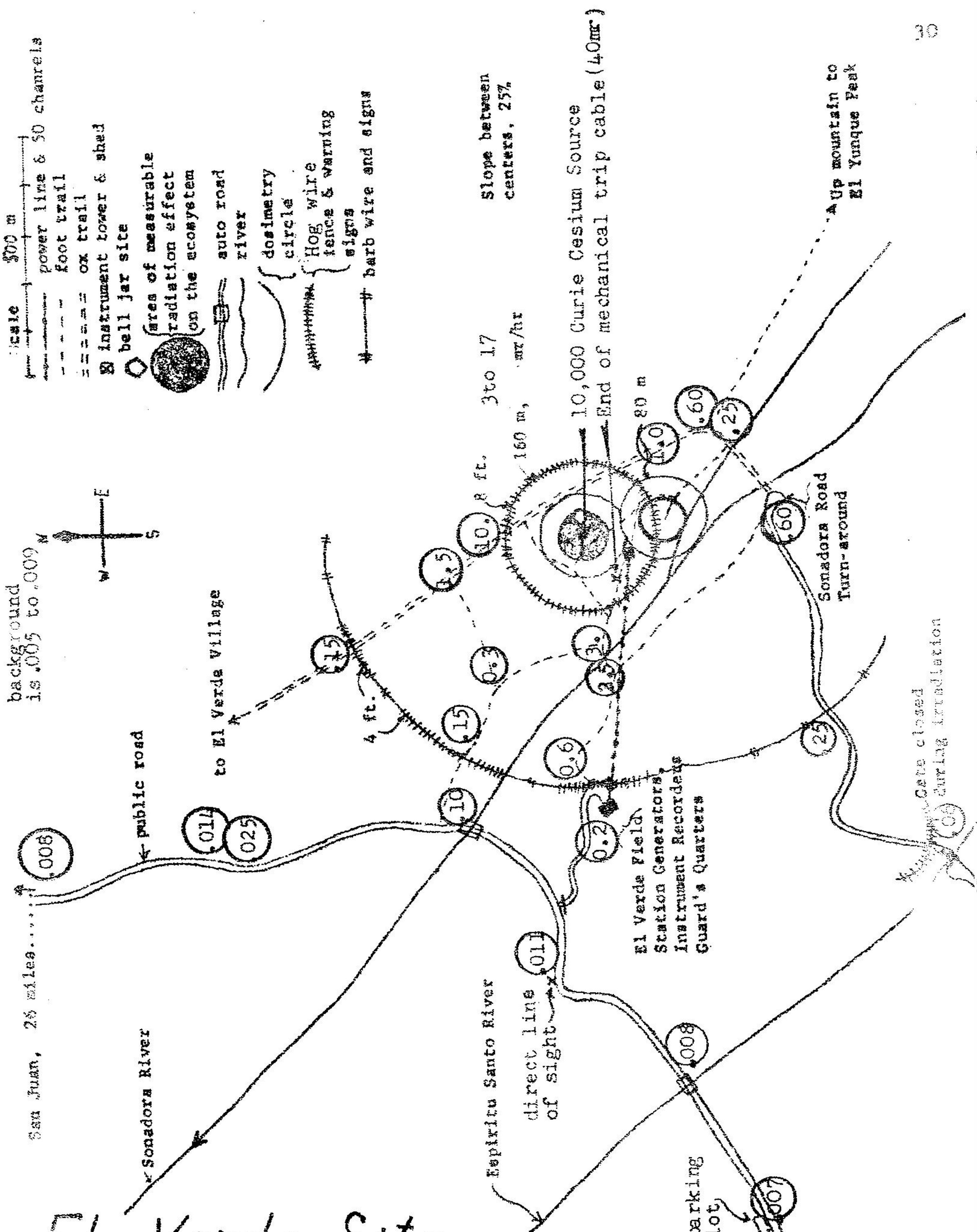


Fig. 4. View of giant metabolic cylinder with plastic partly elevated. Large fan and one of the 6 towers are shown at the right.

Fig. 5. View of 10,000 Curie Cesium source during installation at El Verde in December, 1964 after it was positioned by helicopter.



EL Verde Site

Fig. 6. The El Verde area with measured dosage rates during irradiation given in milli-R per hour (numbers in circles)

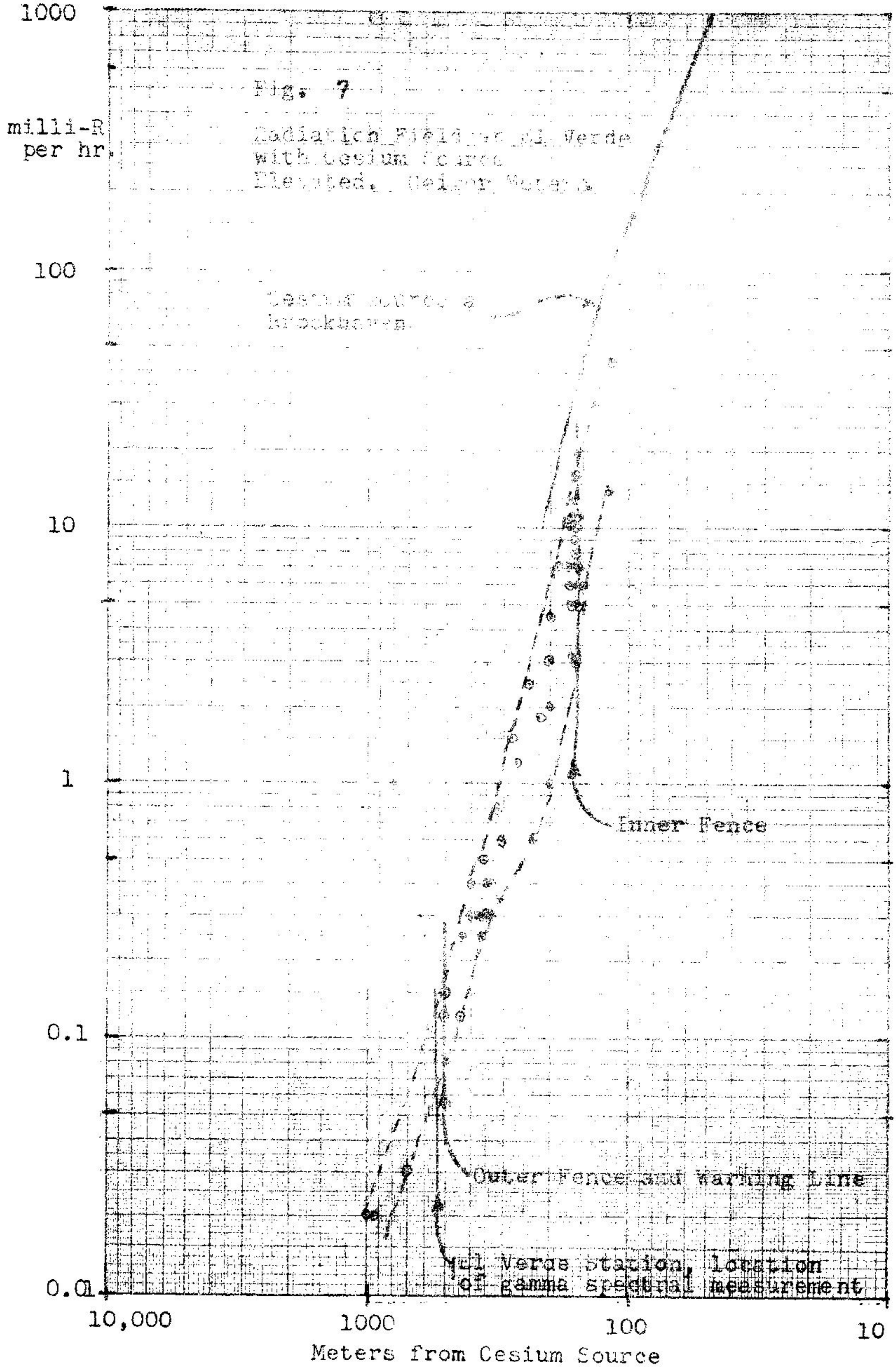
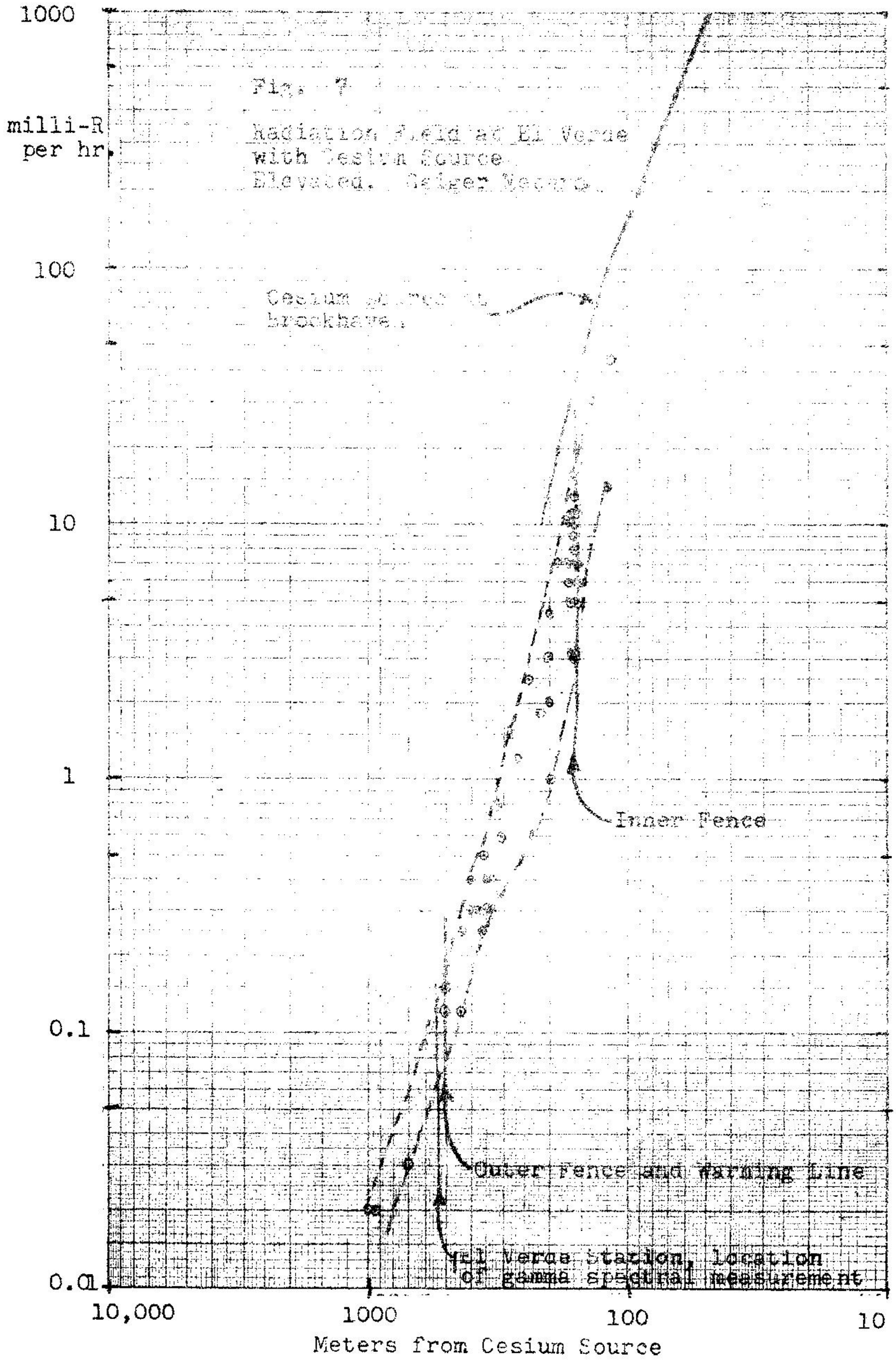
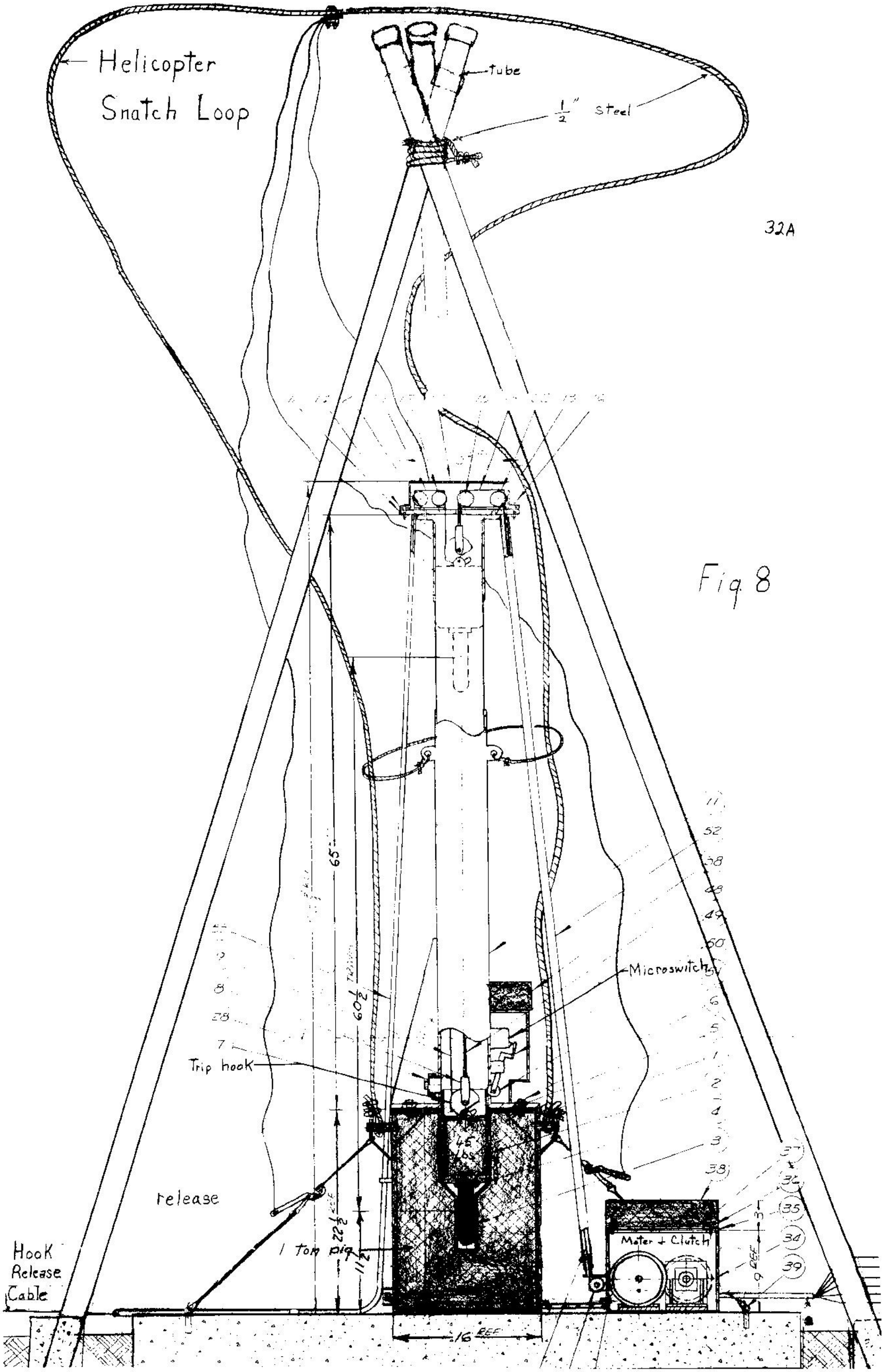


Fig. 7
milli-R
per hr.
1000
100
10
1
0.1
0.01
Inner Fence
Outer Fence and Warning Line
El Verde Station, location
of gamma spectral measurement
10,000
1000
100
10
Meters from Cesium Source



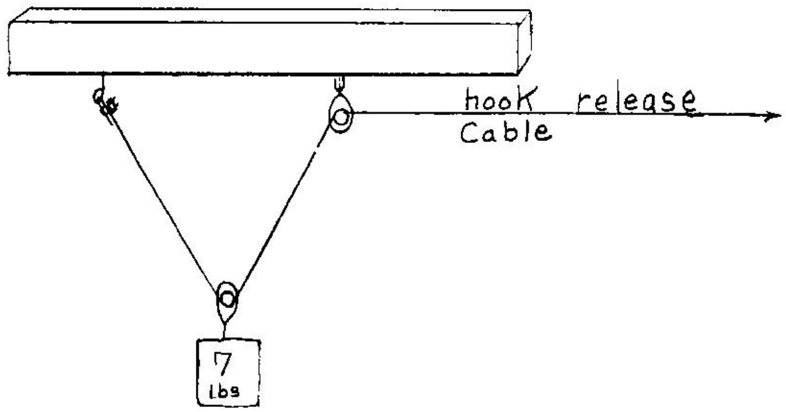
1000
100
10
1
0.1
0.01
milli-R per hr
Fig. 7
Radiation Field at El Verde
with Cesium Source
Elevated. Geiger Record.
Cesium
Brookhaven.
Inner Fence
Outer Fence and Warning Line
El Verde Station, location of gamma spectral measurement
10,000
1000
100
10
Meters from Cesium Source



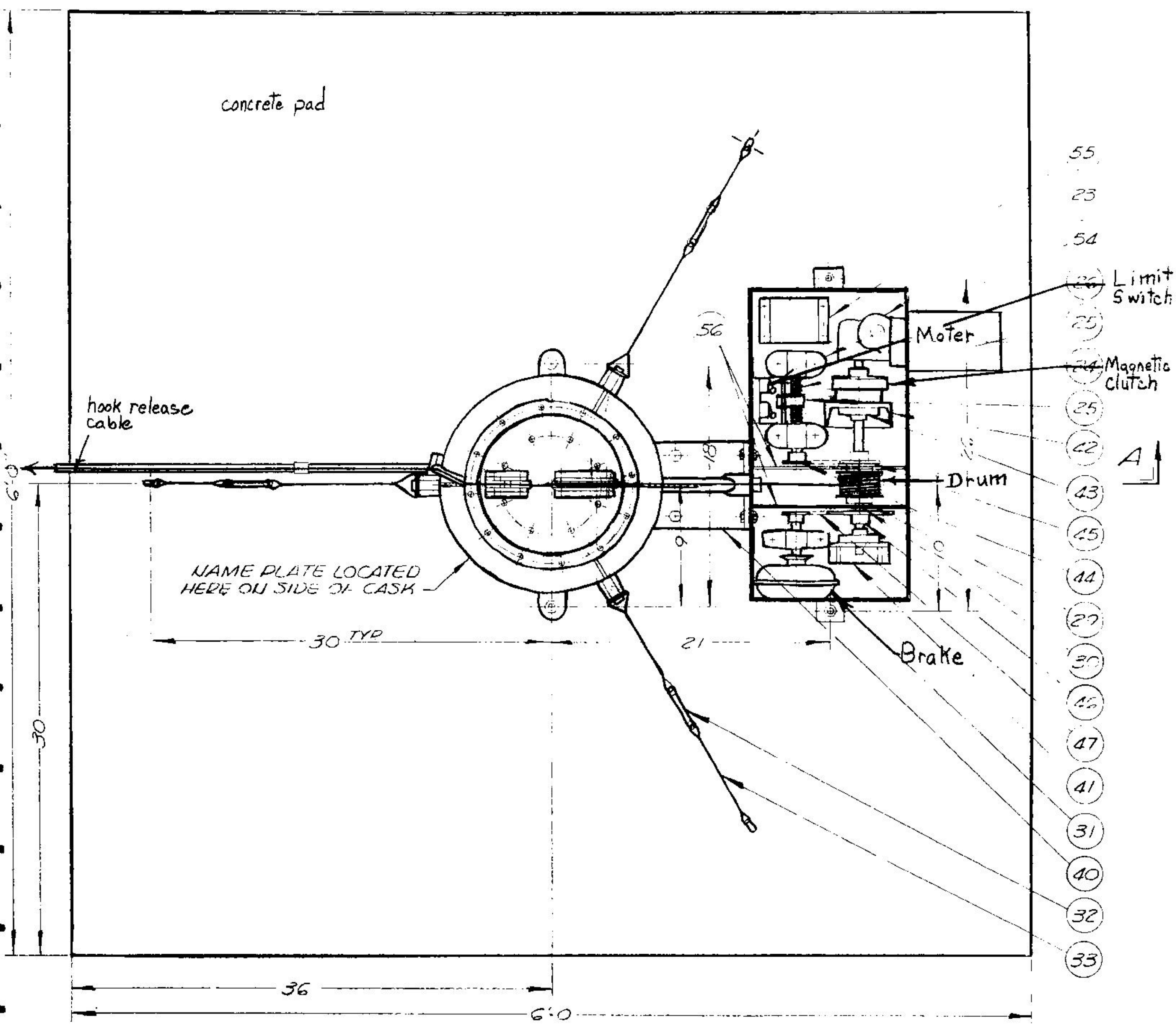
Helicopter Snatch Loop
tube
1/2" steel
Microswitch
Trip hook
release
1 ton pig
Hook Release Cable
Motor + Clutch
65"
60 1/2
22 1/2
11 1/2
16 REF

Fig. 8

Fig. 8



hook release
Cable
400'
7
lbs



concrete pad
hook release
cable
NAME PLATE LOCATED
HERE ON SIDE OF CASK
Limit
Switch
Moter
Magnetic
Clutch
Drum
Brake
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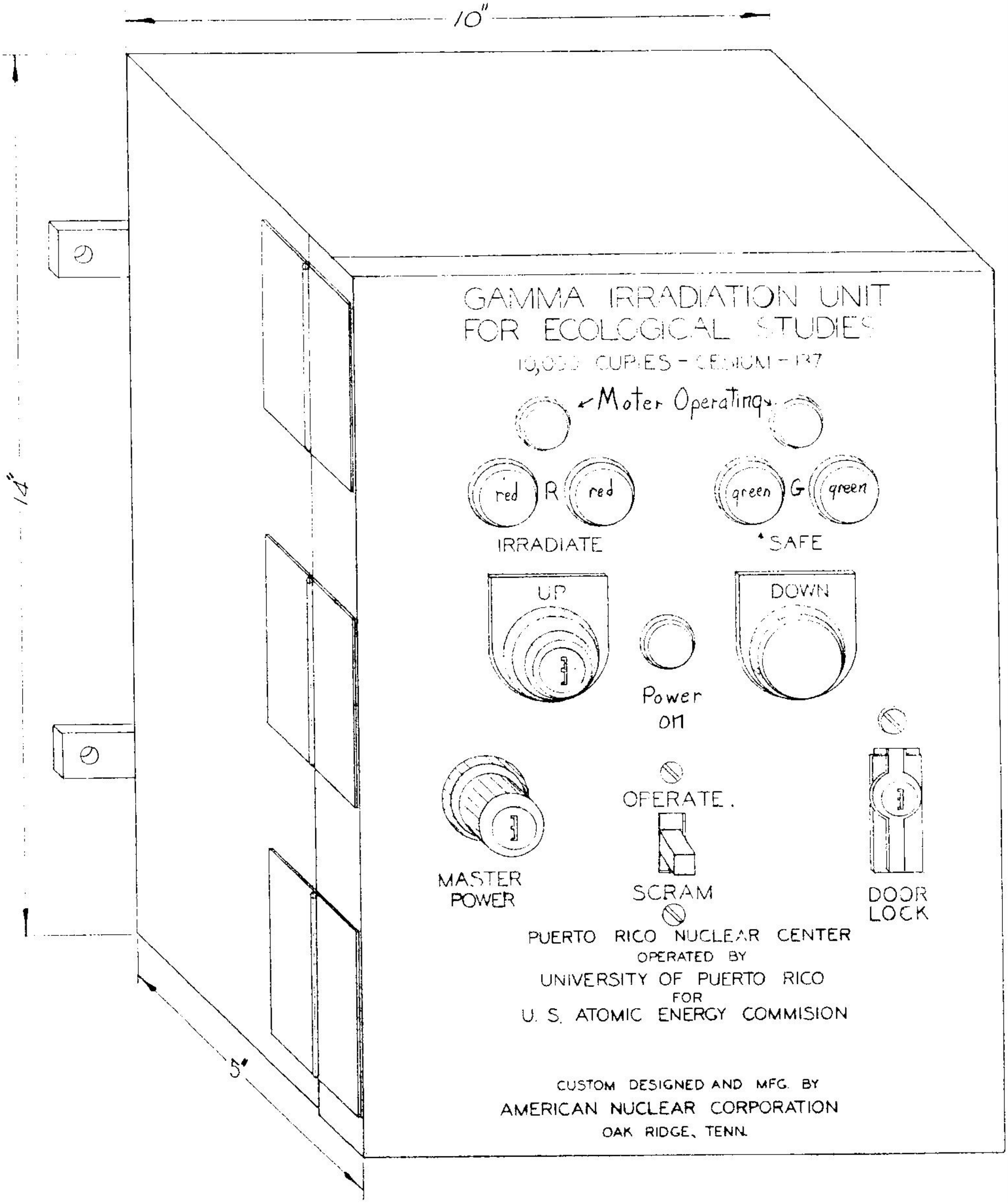
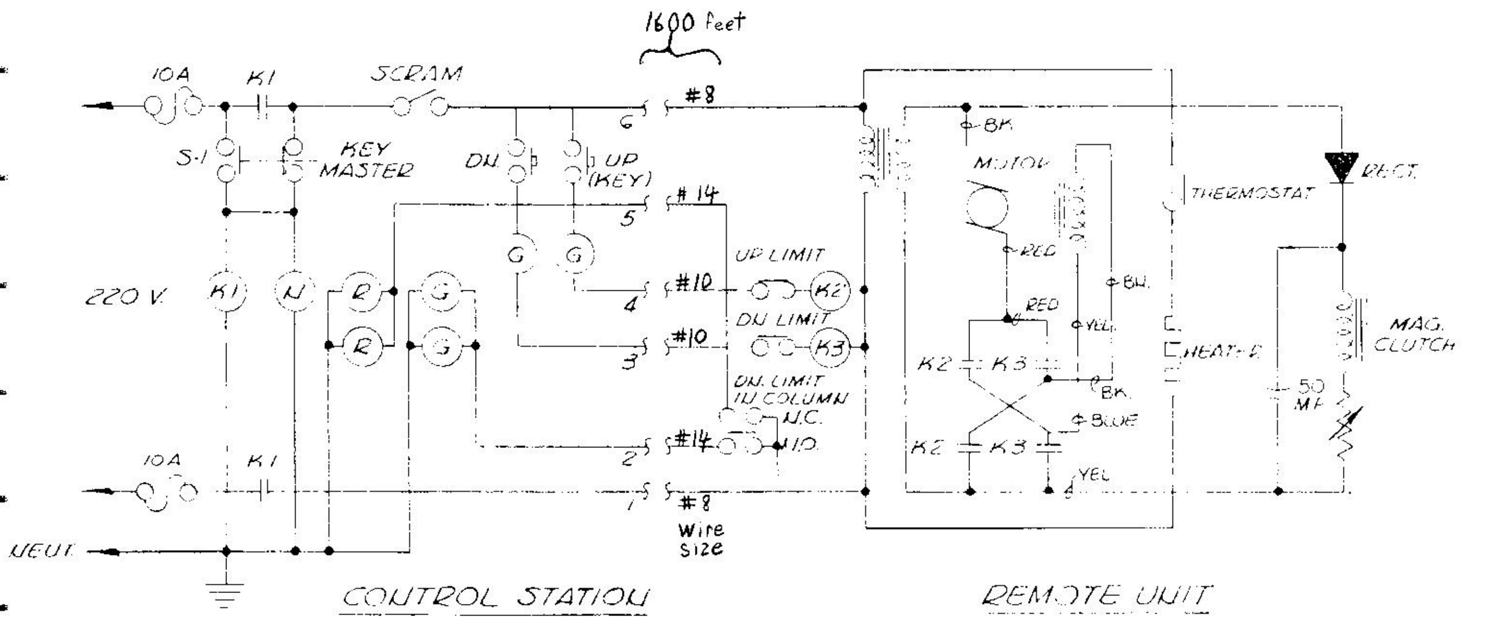
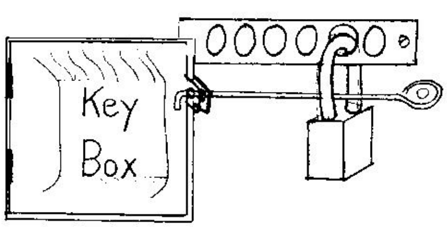

10"
14"
5"
GAMMA IRRADIATION UNIT
FOR ECOLOGICAL STUDIES
10,000 CURIES - CESIUM - 137
Moter Operating
red
R
red
green
G
green
IRRADIATE
SAFE
UP
DOWN
Power
on
MASTER
POWER
OPERATE.
SCRAM
DOOR
LOCK
PUERTO RICO NUCLEAR CENTER
OPERATED BY
UNIVERSITY OF PUERTO RICO
FOR
U. S. ATOMIC ENERGY COMMISION
CUSTOM DESIGNED AND MFG. BY
AMERICAN NUCLEAR CORPORATION
OAK RIDGE, TENN.



CONTROL CIRCUIT SCHEMATIC

Fig 9.



Control of Up Key

			GAMMA RADIATION FACILITY FOR PUERTO RICO RAIN FOREST PROJECT		
			AMERICAN NUCLEAR CORP. P.O. BOX 426 OAK RIDGE, TENN.		
			DRAWN: R.T.J.	CHECKED: B.C.S.	APPROVED:
a	GEN. REV.	B.C.S.	DATE: 11-7-64	SCALE: —	DWG. NO. B-R-3246-1-a

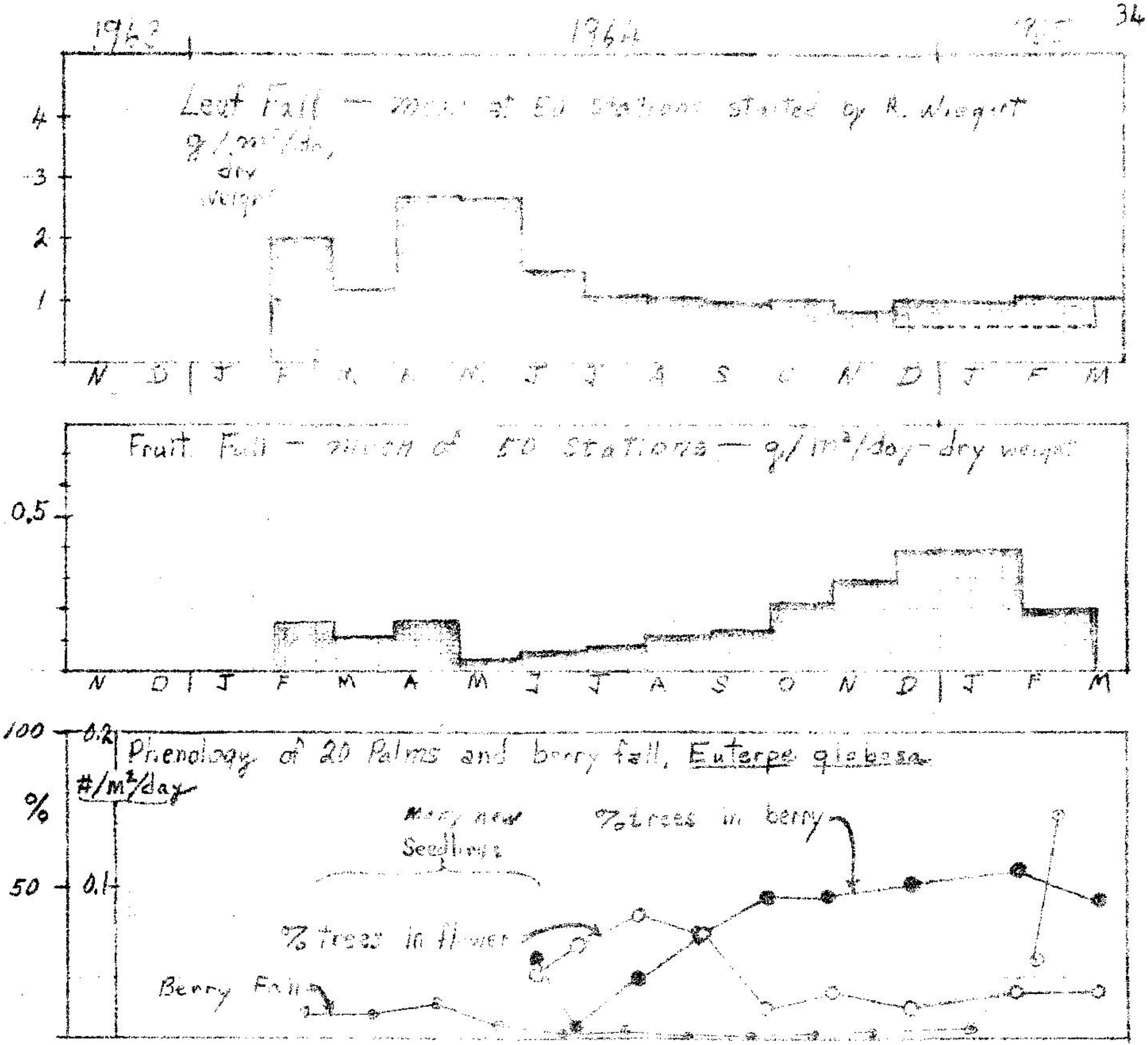
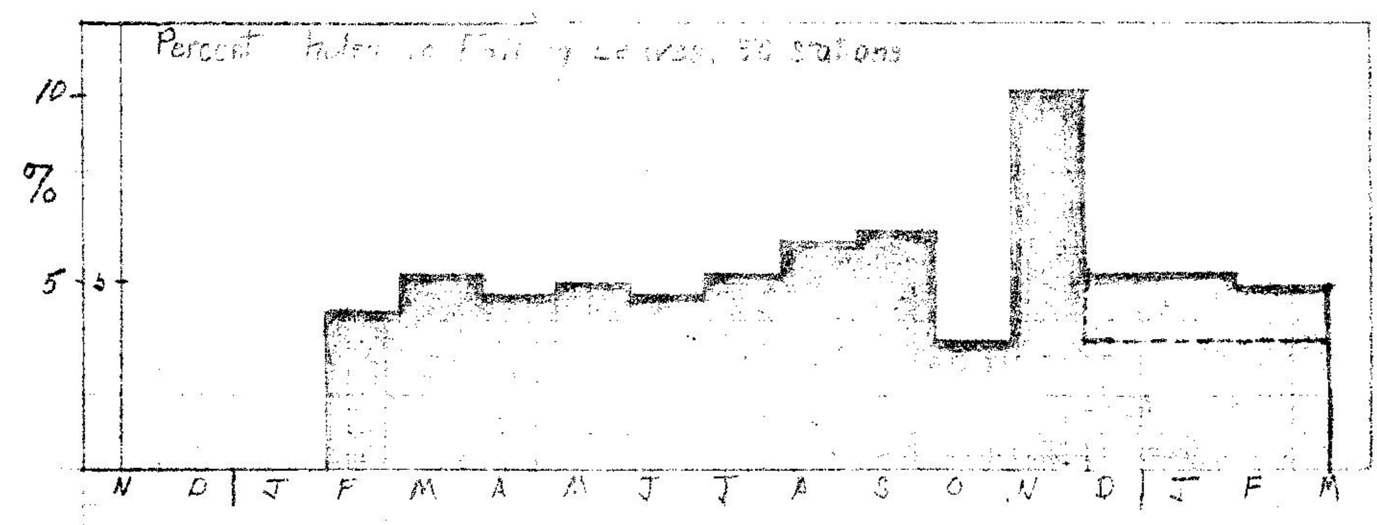


Fig. 10. Record of forest events in the pre-irradiation year



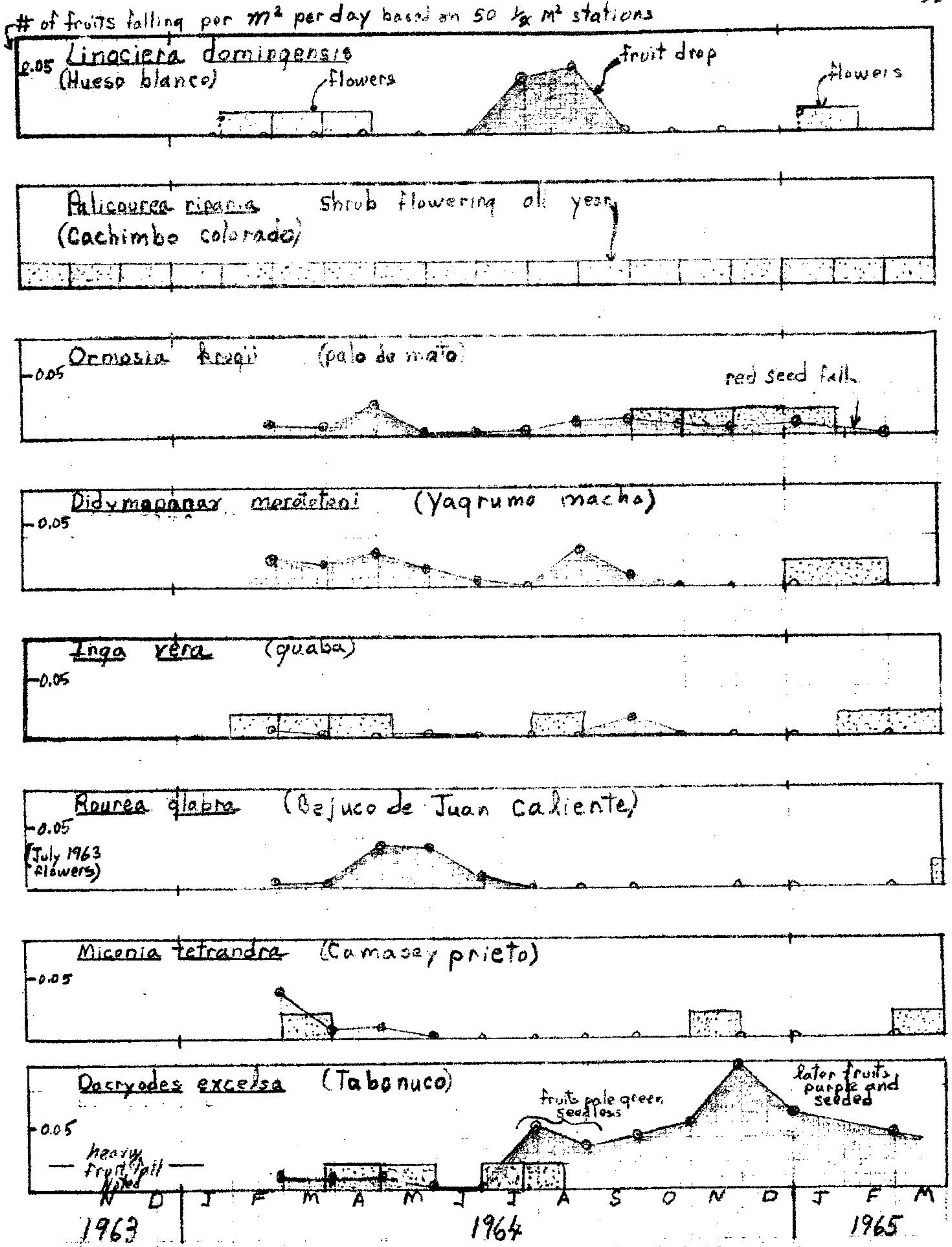


Fig. 11A Phenological records at El Verde at leaf fall stations.

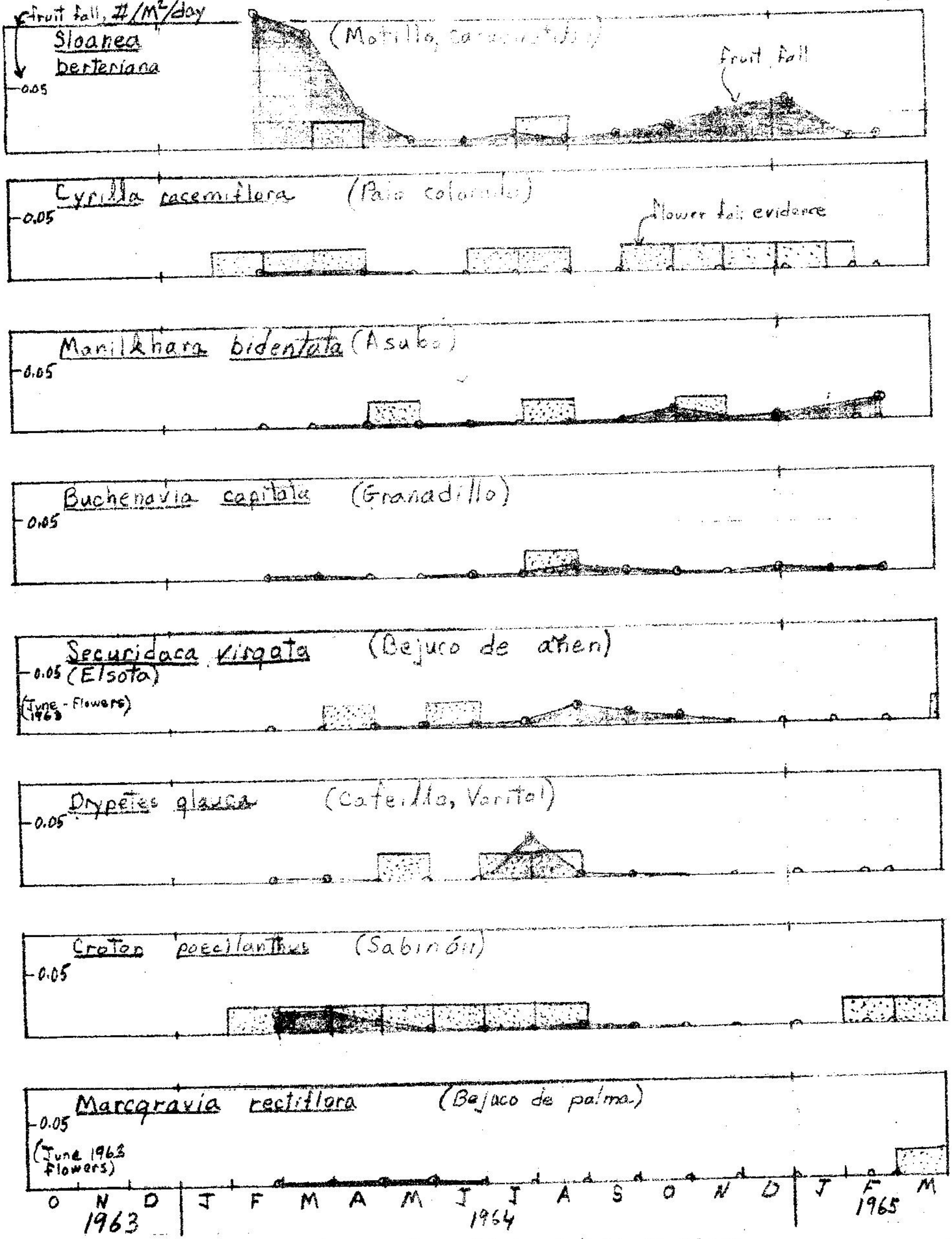


Fig. 11B. Phenological record at 50 leaf fall stations

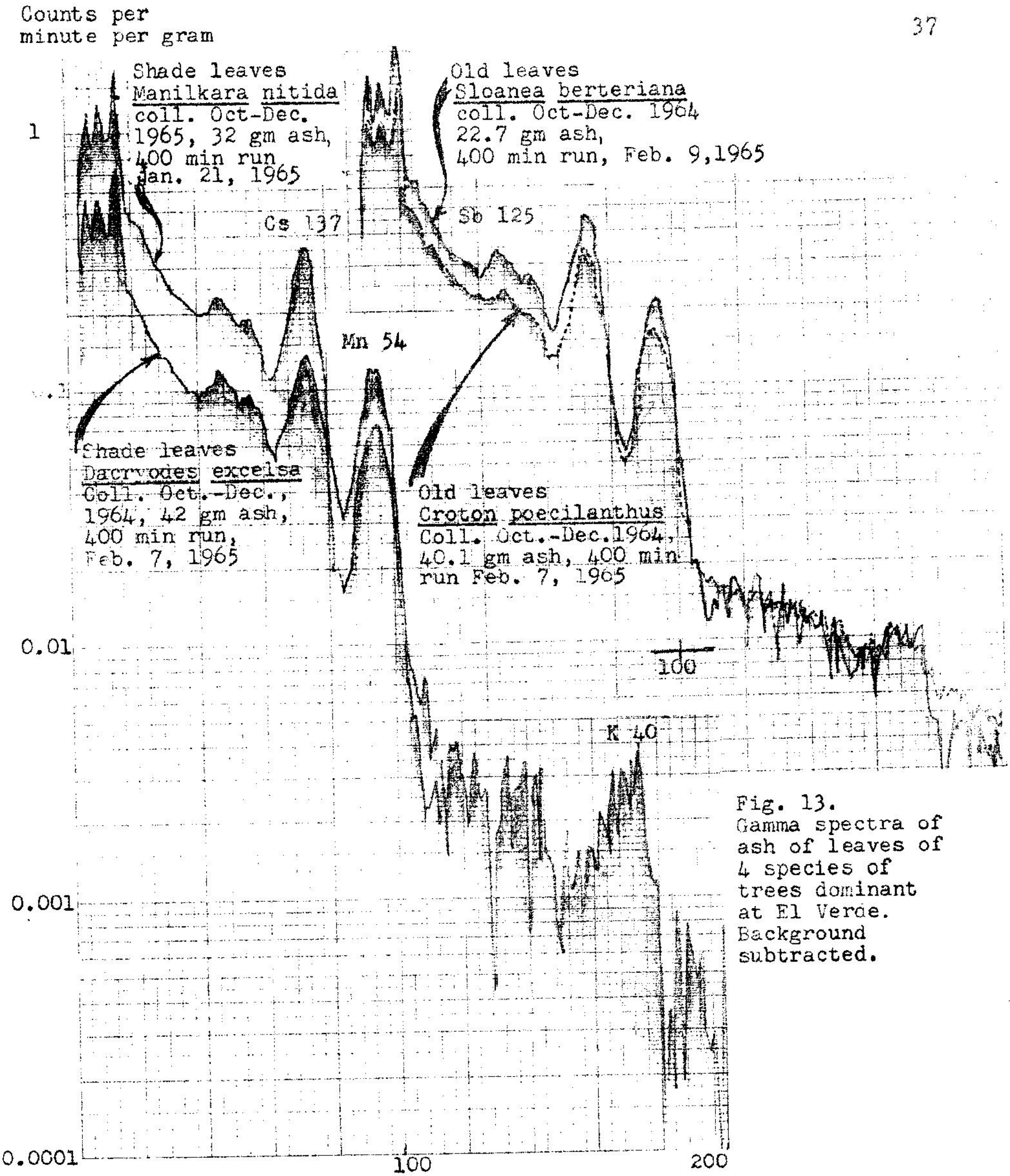


Fig. 13.
Gamma spectra of
ash of leaves of
4 species of
trees dominant
at El Verde.
Background
subtracted.

Fig. 14A. Gamma spectra of forest materials, background subtracted.

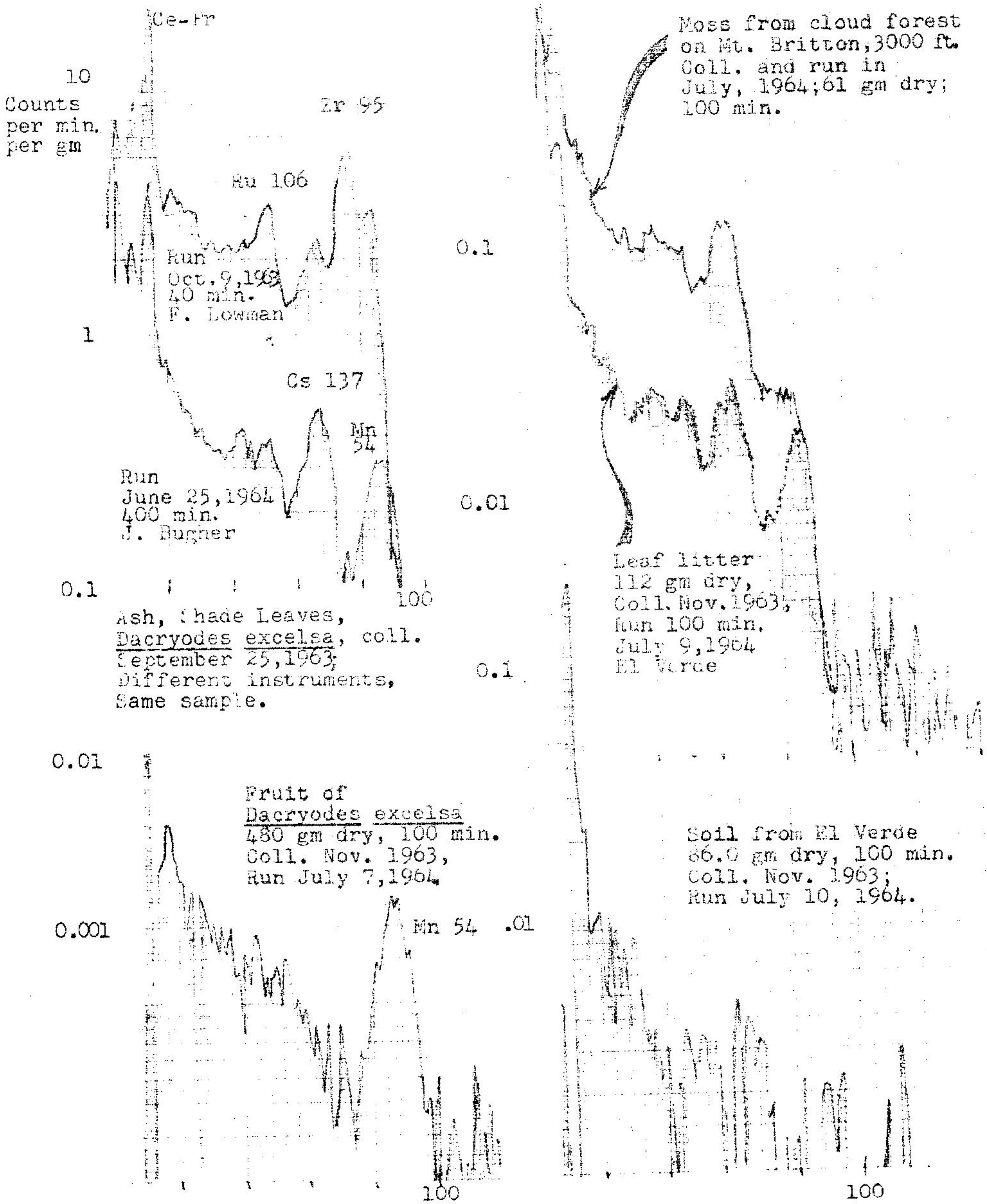


Fig. 14B. Forest materials at El Verde. Gamma spectra, background subtracted. Counts per minute per gram.

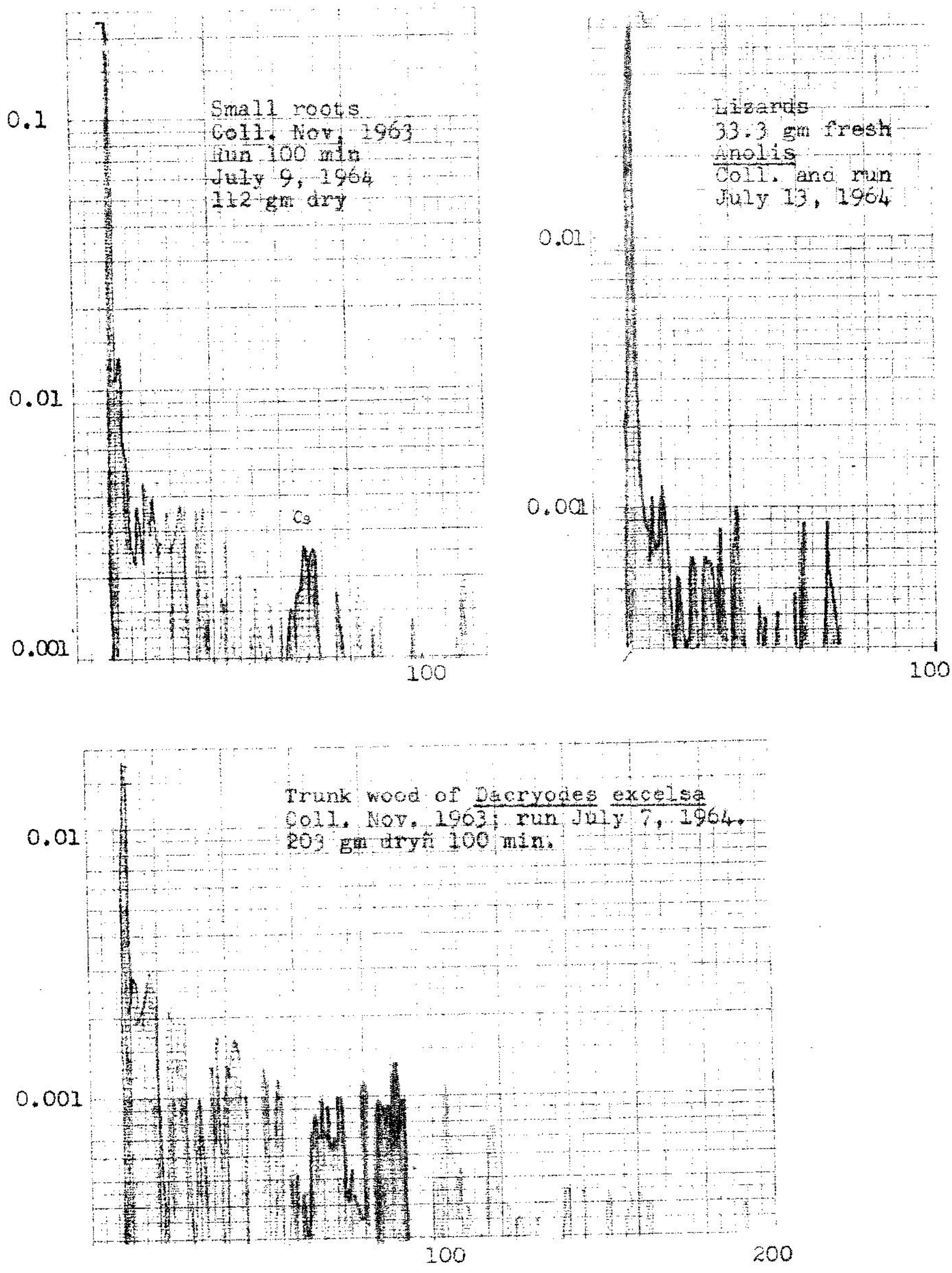


Fig. 15. Gamma spectra taken at El Verde Station with 2 inch crystal unshielded in the open air, March 18,1965, 200 channels, elevation 355 meters above sea level.

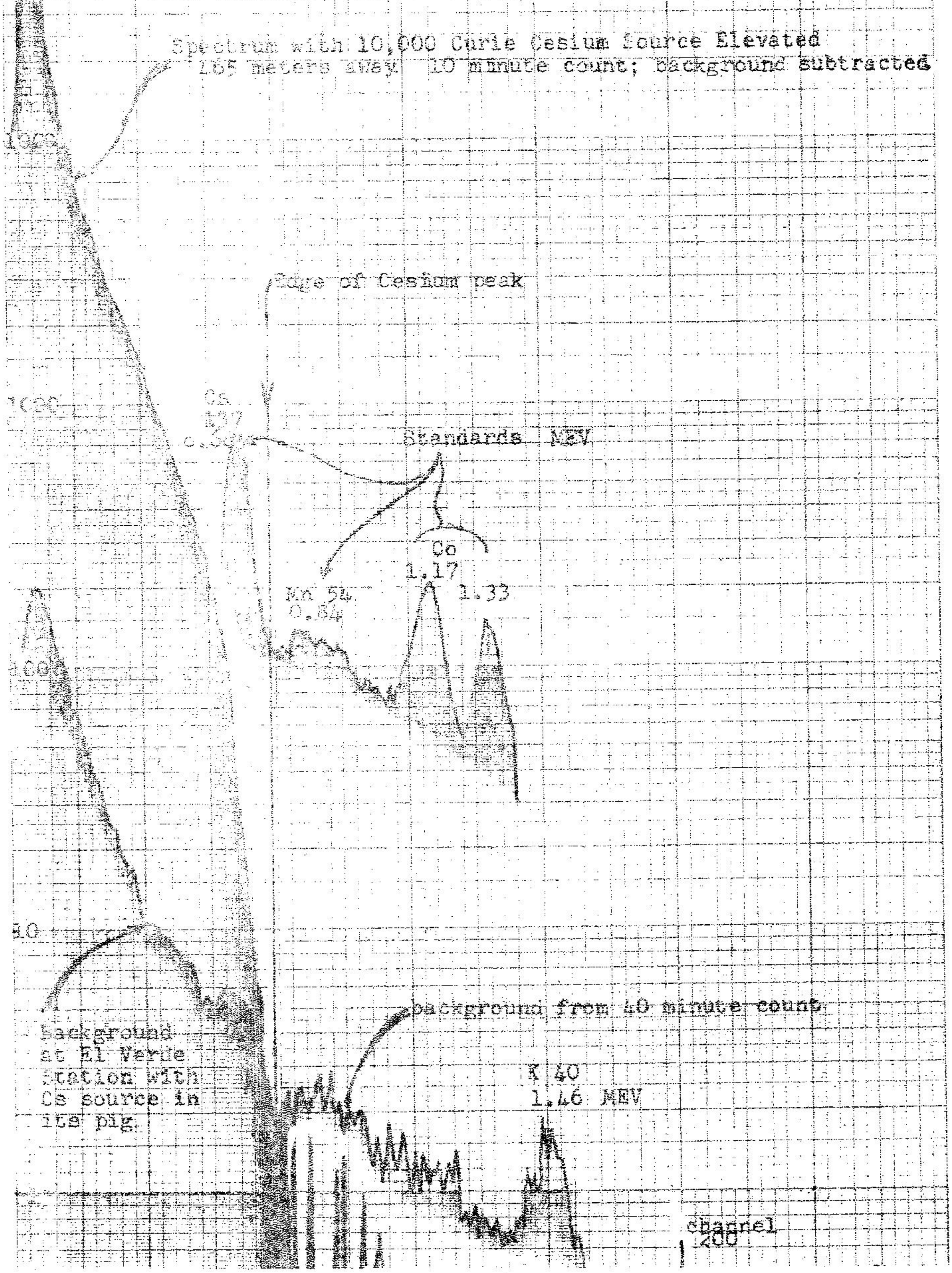
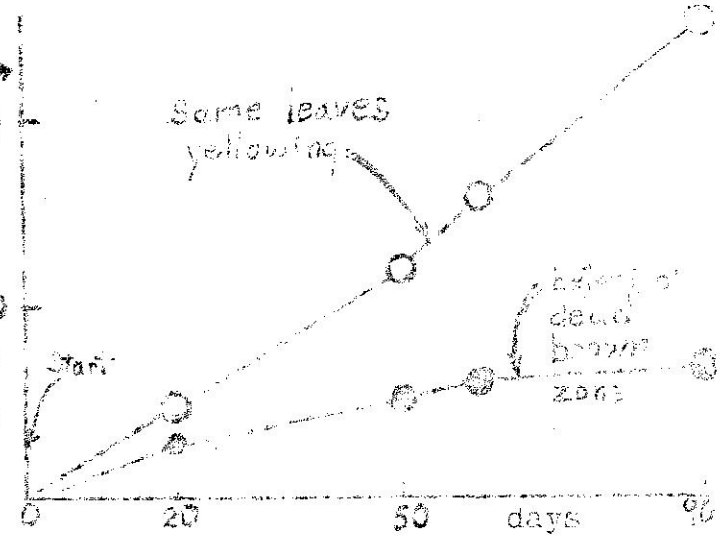
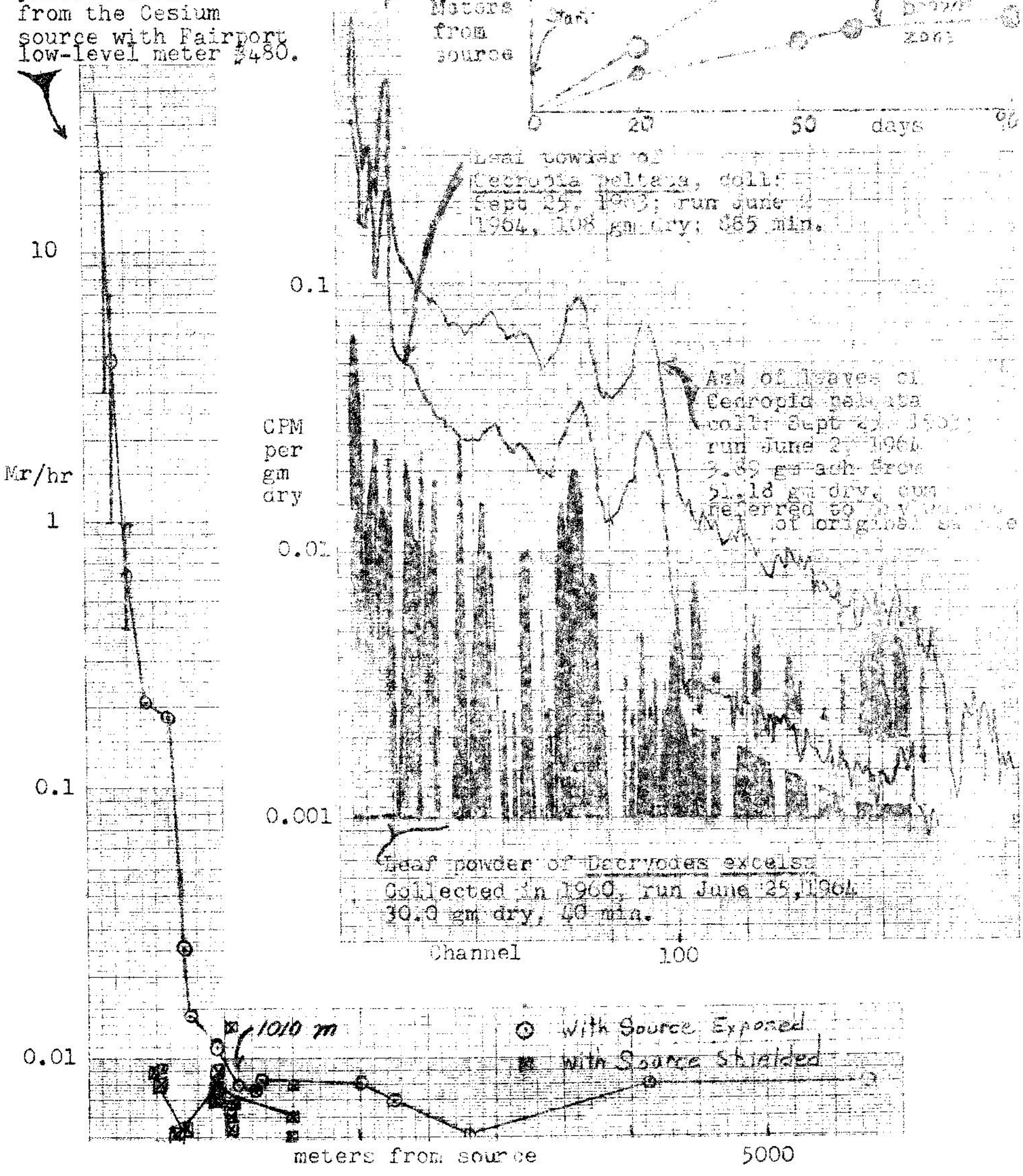


Fig. 16A Spread of radiation effect at El Verde after Jan. 19.

Fig. 16B Gamma spectra of leaves comparing 1960 materials and 1963 leaves in ash and dry form.

Fig. 16C Dosage rate plotted with distance from the Cesium source with Fairport low-level meter #480.





Studies on Five Principal Tree Species

By
Peter Murphy

Tree Growth

The tree growth study involves five of the more common rain forest tree species found in the experimental plots. These species are: Dacryodes excelsa, Manilkara nitida, Croton poecilanthus, Sloanea berteriana, and Cecropia peltata, each representing a different family. Aluminum vernier growth bands have been fitted to 50 specimens of each species, i.e. a total of 250 trees, and are read once monthly for evidence of stem diameter growth; the bands being attached to the bole at approximately 4.5 feet above the ground. Month by month growth of these trees is graphically represented in Fig. 1 (average growth of 25 trees of each species at each center).

A note should be made concerning the validity of the first few months readings. It was suspected that due to the design of the growth bands, which employ a steel spring for achieving tension around the bole, it would probably take a short period of time for the slack to be removed from the band. During this period the full amount of tree growth would not be indicated due to the tightening of the band itself. To check this possibility 25 bands were fitted to trees already having had bands for 10 months. As suspected, a comparison of the two readings after one month showed the new tape to lag the older one by as much as .03 inches diameter change. (See Table 1) Further comparisons will have to be made to determine the period that should be allowed for band adjustment to take place.

From Fig. 1 it is apparent that Dacryodes excelsa is the fastest grower. This species shows only a small amount of growth fluctuation throughout the 10 month period, a slight decrease in growth rate during the summer months. However, Manilkara nitida reached a peak in growth rate during these same summer months. The remaining three species grew fairly uniformly through most of the 10 month period.

It can be seen that in the case of all five species both experimental centers showed very similar growth trends. Manilkara nitida was the major exception and growth appears slightly more rapid in the north center.

Trees used in this study were limited to a diameter of 10 cm. or greater. Specimens in the 20 to 45 cm. diameter class of Dacryodes excelsa (the fastest growing species) showed most rapid growth. The largest individuals of this species ranged up to 65 cm. in diameter. Growth rates varied considerably in all diameter classes.

Flowering and Fruiting

Once each month a one square meter frame is set down at a marked location beneath each of the 250 trees used in the tree growth study. All flowers and fruits, of the same species as the tree beneath which the frame is placed, are counted and removed. Later these data will be correlated with observations of flowering and fruiting in the canopy.

Fig. 2 shows the average number of flowers and fruits of each species found, month by month, at each center. The values are based on 25 frames for each species at each center. The first month should be disregarded since it represents the first removal of accumulated flowers and fruits.

All five species show some degree of fruiting throughout most of the nine month period. Flowers have not yet been recorded for Sloanea berteriana and only during one month for Cecropia peltata and Dacryodes excelsa. The flowers, being light in weight, probably do not tend to fall directly beneath the tree, where the frame is located, as often as do the fruits. Croton poecilanthus however, showed fairly consistent flowering throughout the entire period. Both centers show very similar trends.

Tree Growth Card Format - Card I

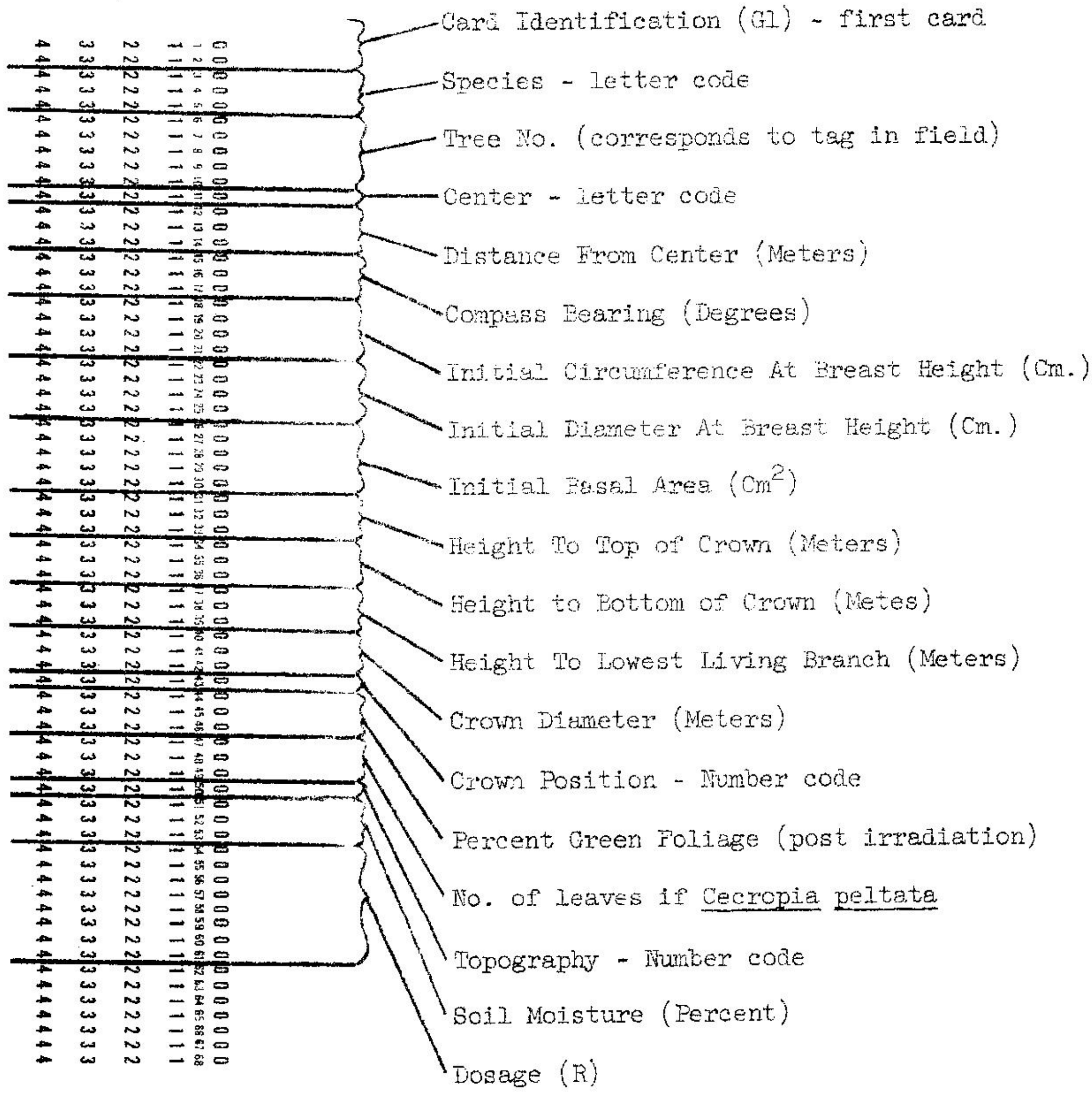


Table 1

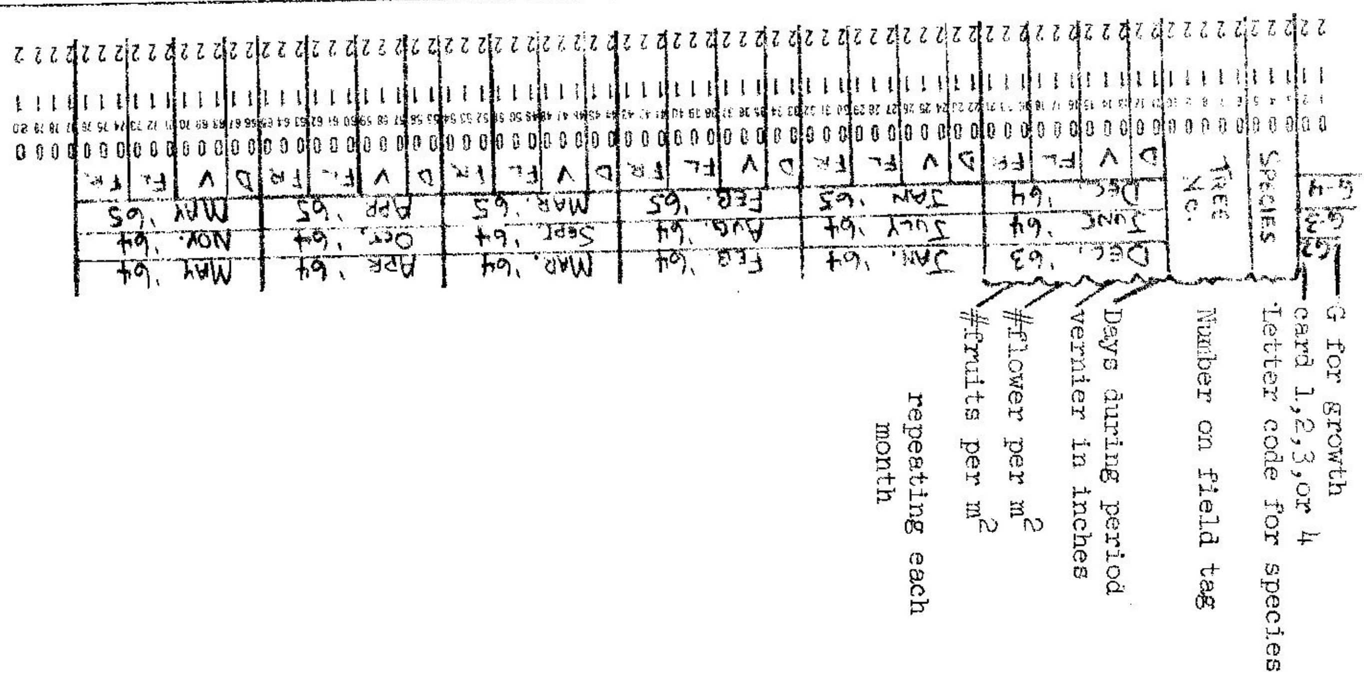
Difference in growth registered in new and old tapes on the same trees.
Data are given in inches circumference change per month.

Species	First Two Months of New Tape				Third Month			
	Old Tape	New Tape	New Tape Lag	%error	Old Tape	New Tape	New Tape Lag	%error
Sloanea berteriana	.09	.03	.06	66	.01	.00	.01	100
	.03	.00	.03	100	.02	.01	.01	50
	.02	.01	.01	50	.01	.00	.01	100
	.06	.04	.02	33	.01	.00	.01	100
	.05	.01	.04	80	.00	.00	.00	-
mean				66				87
Cecropia peltata	.01	.01	.00	100	.00	.00	.00	-
	.14	.10	.04	29	.06	.05	.01	17
	.14	.04	.10	72	.04	.02	.02	50
mean				66				36
Manilkara nitida	.02	.01	.01	50	.00	.00	.00	-
	.05	.02	.03	60	.00	.00	.00	-
	.04	.00	.04	100	.00	.00	.00	-
	.03	.00	.03	100	.00	.00	.00	-
	.01	.01	.00	0	.00	.00	.00	-
mean				62				-
Dacryodes excelsa	.01	.00	.01	100	.00	.00	.00	-
	.01	.01	.00	0	.01	.00	.01	100
	.07	.02	.05	72	.02	.00	.02	100
	.03	.01	.02	66	.00	.00	.00	-
	.07	.02	.05	72	.07	.00	.07	100
	.10	.01	.09	90	.00	.00	.00	-
	.09	.01	.08	89	.00	.00	.00	-
mean				70				100

Cont. Table 1.

Species	First Two Months of New Tape				Third Month			
	Old Tape	New Tape	New Tape Lag	%error	Old Tape	New Tape	New Tape Lag	%error
Croton poecilanthus	.03	.02	.01	33	.02	.00	.02	100
	.07	.02	.05	72	.01	.00	.01	100
	.03	.01	.02	66	.01	.00	.01	100
	.06	.00	.06	100	.04	.03	.01	25
mean				68				81

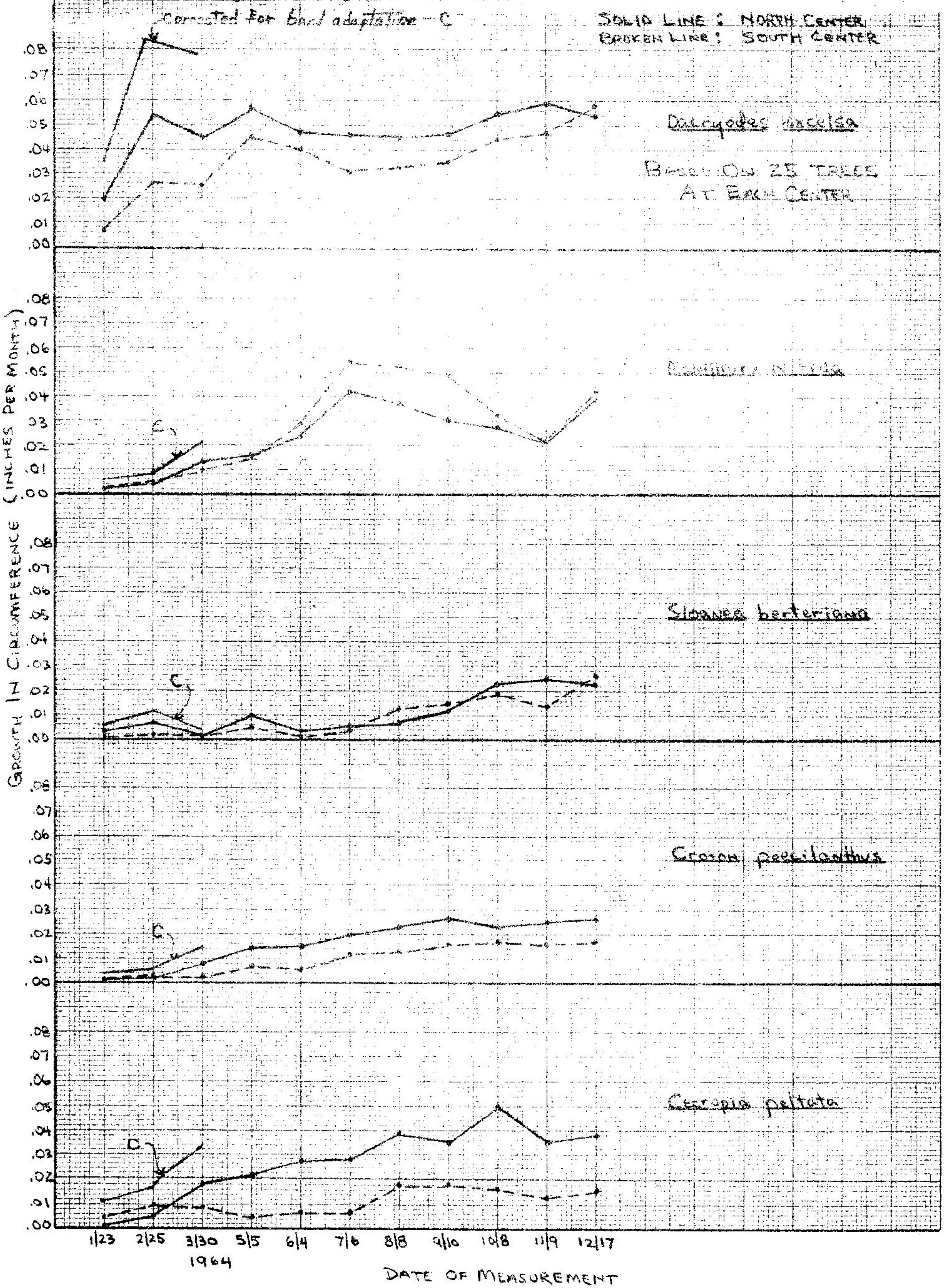
mean percent error = 70%



IBM Card Format
for tree growth data.

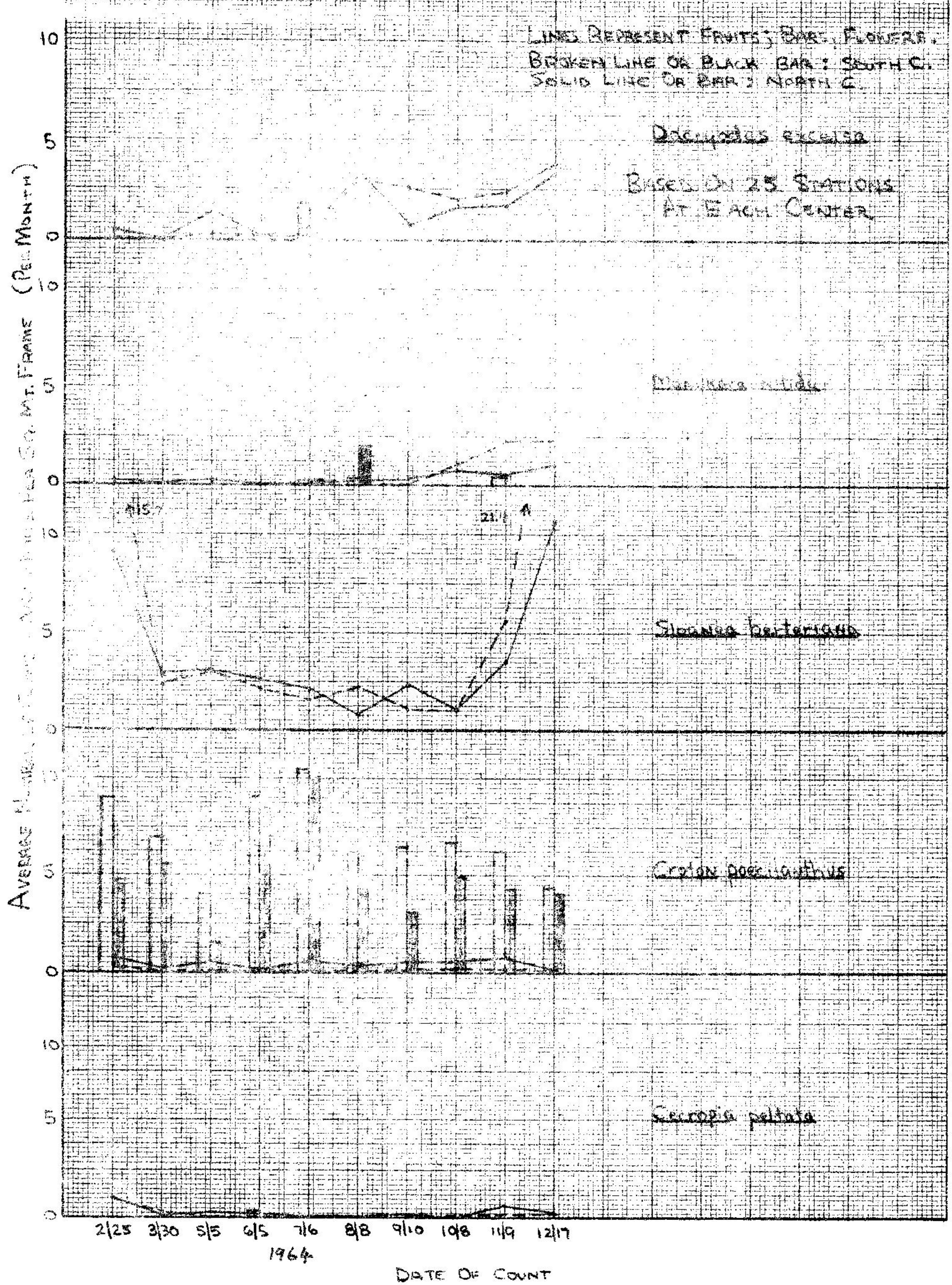
Four cards are required
for each tree including
data through May 65.

FIG. 1. TREE [illegible]



Corrected for band adaptation — C
SOLID LINE: NORTH CENTER
BROKEN LINE: SOUTH CENTER
Dacryodes excelsa
BASED ON 25 TREES AT EACH CENTER
Sloanea berteriana
Croton poecilanthus
Cecropia peltata
C
GROWTH IN CIRCUMFERENCE (INCHES PER MONTH)
.00
.01
.02
.03
.04
.05
.06
.07
.08
1/23
2/25
3/30
5/5
6/4
7/6
8/8
9/10
10/8
11/9
12/17
1964
DATE OF MEASUREMENT

FIG. 2. FLOWERING



Vegetation Structure of the Lower Montane Rain forest at El Verde, and Preliminary Preparations for Measuring the Effect of Radiation on the Forest

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The following are the objectives:

1. To describe the physiognomy of the forest in order to understand its affinity to other tropical rain forests; to define the forest.

2. To describe the species structure and species ecological niches in the forest as a basis for understanding functions and long term succession.

3. To describe the gross radiation effects on the forest.

The following progress has been made:

1. Profile drawing: A profile drawing is complete, except for details, from zero to 80 meters underneath the cable along the SSE line of center II, which is being irradiated. The drawing scale is 1m = 2cm. The drawing is made from a strip five meters wide instead of 7.5m. suggested by Richards in the Tropical Rain Forest. All perennial ferns and spermatophytes are included except seedlings and saplings under 1.4m. in height. Herbs, ferns, epiphytes and lianes are black, understory trees are stippled, transgressives and canopy undividuals are left clear.

The profile drawing is along a line with two fallen trees which allows light penetration and thus good epiphyte and herb growth. The profile will be redrawn after irradiation showing damage and preliminary regeneration. This will serve as the only planned study of the sensitivity of herbs and lianes.

2. Species composition lists are given in Tables 1-5. The following are conclusions drawn from the species lists and from some other data:

This forest is much more diverse in trees than temperate forests though less diverse than some mainland tropical forests. The total number of species represented on the lists is 200.

Over half of the canopy is composed of only five species. If the small species Euterpe and Croton of the palm dominated areas are eliminated, then Dacryodes, Sloanea and Manilkara remain as the overwhelming dominants of the forest.

Four species make up the overwhelming preponderance of understory species (79.1%) although the understory species themselves compose only about one-third of the understory growth. Other species in the understory growth are young of canopy species

Lianes are about half as abundant as canopy trees. Although epiphytes are common, they are not a major component of the forest and are less numerous than in some other tropical forests. Most of the list of epiphytes include.

relatively rare ferns (22-37) and orchids (38-43).

Herb level ground coverage is noticeably lacking in the forest. Some species cover rocks only. About four small plants cover each square meter, but of these only one is an herb (usually the grass Ichnanthus or the fern Dryopteris deltoidea). The others are tree seedlings. Sacrophytes are common.

3. Preliminary calculations suggest that the half-life of a sample of seedlings is about six months..

4. To determine the effect of irradiation on stem-tip growth, six hundred feet of cable were suspended in the forest crown between the two centers as shown on the accompanying map. Twig lengths have been measured on 130 trees. Each tree has ten twigs tagged with a numbered metal band. Post-irradiation measurements should give a measure of the effect of radiation on stem tip growth at various distances. The cable position is drawn in Fig. 2.

Table 1.

Species composition list arranged according to density and in the various synusiae of radiation plots at El Verde.

Canopy trees (species over 10cm. diameter breast height).

Total absolute density: 0.087 trees/m^2 — Relative density below:

1.	Dacryodes excelsa Vahl.	18.2 %
2.	Euterpe globosa Gaertn.	11.4
3.	Croton poecilanthus Urban	9.5
4.	Sloanea berteriana Choisy	8.1
5.	Manilkara bidentata (A., DC.) Cher. synonym M. nitida (Sesse & Moc.) Dubard	6.4
6.	Miconia tetandra (Sw.) D. Don.	5.5
7.	Cecropia peltata L.	4.6
8.	Ormosia krugii Urban	3.1
9.	Matayba domingensis (DC.) Radk	3.0
10.	Inga fagifolia (L.) Willd. synonym Inga laurina (Sw.) Willd	2.7
11.	Linociera domingensis (Lam.) Knobl. synonym Mayepea domingensis (Lam.) Krug & Urban	2.0
12.	Alchornea latifolia Sw.	1.9
13.	Alchorneopsis portoricensis Urban	1.8
14.	Sapium laurocerasus Desf.	1.7
15.	Tabebuia pallida Miers. synonym T. heterophylla (DC.) Britton	1.7
16.	Buchenavia capitata (Vahl) Eichl.	1.6
17.	Micropholis garciniaefolia Pierre	1.6

18.	Ocotea leucoxylon (Sw.) Mez.	1.1
19.	Calycogonium squamulosum Cogn	1.1
20.	Guarea trichilioides L. synonym G. guara (Jacq.) P. Wilson	1.1
21.	Didymopanax morototoni (Aubl.) Decne & Planch	1.0
22.	Inga vera Willd. synonym Inga inga (L.) Britton	1.0
23.	Eugenia stahlii (Kiaersk.) Krug & Urban	.9
24.	Cyrilla racemiflora L.	.9
25.	Myrcia splendens (Sw.) DC.	.9
26.	Guettarda laevis Urban	.9
27.	Casearia sylvestris Sw.	.6
28.	Homalium racemosum Jacq.	.5
29.	Casearia arborea (L. C. Rich) Urban	.5
30.	Cordia sulcata DC.	.5
31.	Ocotea portoricensis Mez.	
32.	Ocotea moschata (Meisn.) Mez.	.5
33.	Casearia bicolor (Urban	.5
34.	Byrsonima spicata (Cav.) DC.	.5
35.	Ficus trigonata L.	.4
36.	Ficus sintenisii Warb.	
37.	Tetragastris balsamifera (Sw.) Kuntze	.4
38.	Miconia prasina (Sw.) DC.	.3
39.	Guatteria caribaea (Urban) synonym Cananga caribaea (Urban) Britton	.3
40.	Casearia guianensis (Aubl.) Urban	.3
41.	Magnolia splendens Urban	.3
42.	Nectandra membranacea (Sw.) Griseb.	.2
43.	Meliosma herbertii Rolfe	.2
44.	Henrietella fascicularis (Sw.) C. Wright	.2
45.	Myrcia deflexa (Poir) DC.	.1
46.	Eugenia jambosa (L.) Millsp.	Species present
47.	Roystonea borinquena O. F. Cook	but not sampled.
48.	Antirhea coriacea (Vahl.) Urban synonym Stenostomum coriaceum (Vahl.) Griseb.	
49.	Antirhea obtusifolia Urban synonym Stenostomum obtusifolium (Urban) Britton & Wilson	
50.	Micropholis chrysophylloides Pierre	
51.	Beilschmiedia pendula (Sw.) Benth. & Hook. synonym Hufelandia pendula (Sw.) Nees	
52.	Pisonia subcordata Sw.	
53.	Byrsonima wadsworthii Little	
54.	Haenianthus salicifolius vars. obovatus Knobl. synonym H. obovatus Krug & Urban	
55.	Cleyera albopunctata (Griseb.) Krug & Urban synonym Eroteum albopunctatum (Griseb.) Britton	
56.	Maytenus ponceana Britton	
57.	Tabernaemontana oppositifolia (Spreug.) Urban	Small...
58.	Malpighia fucata Ker.	stream-side trees
59.	Andira inermis (W. Wright) H. B. K.	Trees seen
60.	Mangifera indica L.	only as seedlings or
61.	Calophyllum brasiliense Camb.	saplings.

Table 2.

Understory trees species which reproduce under the main canopy and do not usually grow to the canopy.

Total absolute density: 0.224 trees/m^2
Total density including all plants from
1.4m tall to 10cm DBH: 0.725 trees/m^2

No.	Species	Relative density below:
1.	Palicourea riparia Benth.	41.5%
2.	Drypetes glauca Vahl.	19.4
3.	Cordia borinquensis Urban	10.7
4.	Hirtella rugosa Pers.	7.4
5.	Psychotria berteriana DC.	3.8
6.	Myrcia ?	3.6
7.	Trichilia pallida Sw.	3.3
8.	Ixora ferrea (Jacq.) Benth	2.9
9.	Lasianthus lanceolatus (Griseb.) Urban	1.9
	synonym L. moralesii (Griseb.) C. Wright	
10.	Cassipourea guianensis Aubl.	1.5
	synonym C. alba Griseb.	
11.	Ocotea spathulata Mez.	.7
12.	Guarea ramiflora Vent.	.7
13.	Comocladia glabra (Schultes) Spreng.	.7
14.	Daphnopsis philippiana Krug & Urban	.3
15.	Ardesia glauciflora Urban	.3
	synonym Icacorea glauciflora (Urban) Britton	
16.	Wallenia pendula (Urban) Mez.	.3
	synonym Petesioides pendulum (Urban) Britton	
17.	Piper treleaseanum Britton & Wilson	.3
18.	Urera baccifera (L.) Gaud.	.2
19.	Piper amalago L.	.2
20.	Ditta myricoides Griseb.	.1
21.	Samyda spinulosa Vent.	.1
22.	Piper aduncum L.	
23.	Ilex sideroxyloides (Sw.) Griseb.	
24.	Psychotria maleolens Urban	
25.	Psychotria patens Sw.	
26.	Psychotria uliginosa Sw.	
27.	Brunfelsia portoricensis Krug & Urban	
28.	Mecranium amygdalinum (Desr.) C. Wright	
29.	Myrcia berberis DC.	
30.	Hedyosmum arborescens Sw.	
31.	Coccolobis pirifolia Desf.	
32.	Citharexylum caudatum L.	
33.	Turpinia paniculata Vent.	
34.	Miconia racemosa (aubl.) DC.	34--38 are small
35.	Miconia sintenisii Cogn.	trees which need
36.	Miconia guianensis (DC.) Cogn.	open sunlight.
37.	Cyathea arborea (L.) J. E. Smith	
38.	Piptocarphia tetandra Urban	

Table 3.

Lianes, woody vines which grow into the canopy.
Total absolute density: 0.133 lianes/m^2 Rel. density below:

1.	Rourea glabra Griseb.		28.4%
2.	Philodendron krebsii Schott		18.0
3.	Marcgravia rectiflora Tr.		14.0
4.	Heteropteris laurifolia (L.) Juss. synonym Banisteria laurifolia L.		13.7
5.	Schlegelia brachyantha Griseb. synonym S. portoricensis (Urban) Britton		4.9
6.	Neorudolphia volubilis (Willd.) Britton		4.0
7.	Securidaca virgata Sw. synonym Elsota virgata (Sw.) Küntze		4.0
8.	Paullinia pinnata L.		3.4
9.	Ipomoea repanda Jacq. synonym Exogonium repandum (Jacq.) Choisy		3.2
10.	Doliocarpus calinoides (Eichl.) Gilg.		2.0
11.	Philodendron lingulatum (L) C. Koch.		1.4
12.	Cissus sicyoides L.		1.2
13.	Hippocratea volubilis L.		.9
14.	Smilax coriacea Spreng.		.6
15.	Forsteronia corymbosa (Jacq.) G. F. W. Meyer		.3
16.	Cissampelos pareira L.		
17.	Clusia gundlachii Stahl	Clusia actually epiphytic but with aereal roots	
18.	Clusia rosea Jacq.		
19.	Rajania cordata L.		
20.	Mikania fragilis Urban		
21.	Mikania pachyphylla Urban		
22.	Chamissoa altissima (Jacq.) H. B. K.		
23.	Tournefortia hirsutissima L.		

Table 4.

Epiphytes, species without terrestrial attachment, growing on other plants.
Total absolute density (expressed as plants/m^2 if the epiphytes were brought vertically to the ground): 0.472 plants/m^2

Relative density below:

1.	Trichomanes capillaceum L.	40.1%
2.	Guzmania berteroniana (R&S) Mez.	28.0
3.	Nephrolepis rivularis (Vahl.) Mett	8.5
4.	Elaphoglossum flaccidum (Fee) Moore	5.8
5.	Polypodium lycopodioides L.	3.7
6.	Epidendrum spp.	3.2
7.	Elaphoglossum dussii Underw.	2.6
8.	Polypodium chnoodes Spreng.	1.6
9.	Vriesia macrostachya (Vello) Mez.	1.6
10.	Hillia parasitica Jacq.	1.6

11.	Oleandra articulata (Sw.) Presl.	.5
12.	Elaphoglossum herminieri (Bory & Fee) Moore	.5
13.	Lycopodium linifolium L.	.5
14.	Columnea tulae Urban	.5
15.	Hohenberbia portoricensis Mez.	.5
16.	Pleurothallis foliata Griseb.	.5
17.	P. ruscifolia (Jacq.) R. Br.	.5
18.	Phoradendron piperoides (H.B.K) Trel.	
19.	Guzmania lingulata (L.) Mez.	
20.	Catopsis floribunda (Brongn.) L.B. Smith	
21.	Lycopodium funiforme Bory	
22.	Trichomanes punctatum Poir.	
23.	T. crispum L.	
24.	Polypodium polypodioides (L.) Watt	
25.	Elaphoglossum pteropus C. Chr. Ind.	
26.	E. apodum (Kaulf.) Moore	
27.	E. flaccidum (Feé) Moore	
28.	Hymenodium crimitum (L.) Feé	
29.	Polypodium astrolepis Liebm.	
30.	Cochlidium seminudum (Willd.) Maxon	
31.	Vittaria filifolia Feé	
32.	Polypodium crassifolium L.	
33.	Asplenium serratum L.	
34.	Polypodium aureum L.	
35.	P. taenifolium Jenman	
36.	P. loriceum L	
37.	Asplenium cuneatum Lam.	
38.	Jaquiniella globosa (Jacq.) Schlechter	
39.	Ornithidium coccimeum (Jacq.) Salisb.	
40.	Polystachya extinctoria Rchb.	
41.	Epidendrum cochleatum L.	
42.	Epidendrum corymbosam Lindl.	
43.	Epidendrum sp.	

Table 5

Herbs (reproducing ground species)

Total absolute density: 1.44 herbs/m^2
Density including seedlings: 4.16 plants/m^2

		Relative density below:
1.	Ichnanthus pallens (Sw.)	32.9%
2.	Pilea krugii Urban	26.6
3.	Dryopteris deltoidea (Sw.)	11.4
4.	Arthrostylidium sarmentosum Pilger	8.9
5.	Alsophila borinqueña Maxon	8.2
6.	Peperomia emarginella (Sw.)	3.2
7.	Polypodium duale Maxon	3.2
8.	Erythrodes plantaginea (L.) Lindl.	1.9
9.	Selaginella krugii Hieron	1.9
10.	Gymnosiphon portoricensis Urban	.6
11.	Elaphoglossum rigidum (Aubl.) Urban	.6
12.	Anthurium dominicense Schott	.6
13.	Adiantum cristatum L.	

14. *Anthurium acaule* (Jacq.) Schott
15. *Begonia decandra* Pav.
16. *Scleria* sp.
17. *Selaginella portoricensis* A. Br.
18. *Apteria aphylla* (Nutt.) Burm.
19. *Erythrodes hirtellus* (Sw.) Lindl.
20. *Triphora surinamensis* (Lindl.) Britton
21. *Phaeocphaerion persicariaefolius* (DC.) C.B. Clarke
22. *Pitcairnia angustifolia* (Sw.) Rediute
23. *Heliconia bihai* L.
24. *Gonolobus variifolia* (Schlechter) Britton
25. *Pilea obtusata* Liebm.
26. *Pilea semidentata* (Juss.) Wedd.
27. *Trichomanes rigidum* Sw.
28. *Danaea nodosa* (L) J. E. Smith
29. *D. elliptica* J. E. Smith
30. *Dryopteris effusa* (Sw.) Urban
31. *Dryopteris reticulata* (L.) Kaulf.
32. *Polybotraya cervina* (L.) Kaulf.
33. *Rhipidopteris peltata* (Sw.) Schott
34. *Nephrolepis biserrata* (Sw.)

5. To determine the effect of irradiation on leaf fall, 179 low understory trees were tagged and the leaves counted on one branch of each plant. All low trees were tagged inside thirty meters in the area being irradiated. Many *Palicourea riparia* and *Hirtella rugosa* were tagged outside thirty meters in the site being irradiated and in the control site. All tags bear the letter "L". Post-irradiation leaf counts will show leaf fall. These data can be compared with leaf fall data being collected in the canopy trees.

6. Some soil moisture data were taken to determine similarity or dissimilarity of sites. Soil was collected after three days without rain. A tendency was found toward less soil moisture on the ridge sites (centers I, II, and III) versus the poorly-drained, palm dominated areas. Some statistical significance was established (Fig. 7). Areas of soil sampling are drawn in Fig. 2.

Note to Project Participants: This is the list of higher plant species in the El Verde study areas. Much work has already been recorded using the code list in last year's (1964) report. This new list corrects error in the earlier table and includes name changes now being recognized in taxonomic work such as in the papers by James Duke and the new book by Little and Wadsworth.

To avoid confusion on the project we suggest that the whole latin names be used rather than the code (except on the IBM cards). Remember that the 7000 aluminum tags on the trees may have the older name. HTO

Table 7

List of Common Plant Species of El Verde Radiation Site.
Symbol, Latin Name, Spanish Name, Important Synonyms.

Changes made from last year's report are underlined to aid those making corrections.

Ab - Alsophila borinquena - Palmilla grande
Ad - Anthurium dominicense
Al - Alchornea latifolia - Achiotillo
Ap - Alchorneopsis portoricensis - Palo de gallina, (palo de pollo
Bc - Buchenavia capitata - Granadillo
Bl - Heteropteris laurifolia (Banisteria l.) Bejuco de sonadora (vine)
Bs - Byrsonima coriacea (B. spicata) Maricao amarillo (M. colorado)
Ca - Casearia arborea Rabo de ratón
Cb - Cordia borinquensis Palo de muñeco
Cbi- Casearia bicolor Talantrón o Cuero de Sapo (Yunquea)
Cc - Guatteria caribaea (Cananga c.) Ilán-ilán
Cep- Cecropia peltata Yagrumo hembra
Cg - Casearia guianensis Palo blanco
Clg- Clusia gundlachii Cupey o Cupeillo de altura
Cog- Comocladia glabra Carasco
Cp - Croton poecilanthus Sabinón
Cpa- Cassipourea guianensis (C.alba) otro Teta de burra
Cr - Cyrilla racemiflora Palo colorado
Cs - Casearia sylvestris Palo de cotorro (Palo blanco)
Csq- Calycogonium squamulosum Jusillo o Camasey jusillo
Csl- Cordia sulcata Moral
(Css) Dc - Doliocarpus calinoides Bejuco de agua (vine)
De - Dacryodes excelsa Tabonuco
Dg - Drypetes glauca Varital (cafeíllo)
Dm - Didymopanax morototoni Yagrumo macho
Dd - Dryopteris deltoidea Palmilla pequeña
Dp - Daphnopsis philippiana Majagua de sierra
Eg - Euterpe globosa (Prestoea montana) Palma de sierra
Er - Ipomoea repanda (Exogonium repandum) Suelda consuelda
Es - Eugenia stahlii Guayabota
Ev - Securidaca virgata (Elsota virgata) Bejuco de añen (vine)
Fc - Ficus trigonata (F. crassinervia) Jaguey colorado

Table 7 - Cont.

Fl - Ficus laevigata (F. citrifolia) Jaguey blanco
Gg - Guarea trichilioides (G. guara) Guaraguao
Gl - Guettarda laevis Cucubano
Gr - Guarea ramiflora Guaraguaillo
Hf - Henrietella fascicularis Tipo de camasey
Hor- Homalium racemosum Caracolillo
Hr - Hirtelia rugosa Teta de burra
If - Ixora ferrea Palo de clavo
Ig - Ardesia glauciflora (Icacorea g.) Ausubón
Il - Inga laurina (Inga fagifolia) Guamá
Ip - Ichnanthus pallens
Iv - Inga vera Guava
Mc - Linociera domingenis (Mayepea d.) Hueso blanco
Lm - Lasianthus lanceolatus (L. moralesii) Mata de peo
Mgs- Magnolia splendens Laurel sabinón
Md - Matayba domingensis Negra lora
Myd- Myrcia deflexa Cieneguillo
Mg - Micropholis garciniaefolia Caimitillo verde
Mh - Meliosma herbertii Aguacatillo
Mn - Manilkara bidentata (M. nitida) Ausubo
Mr - Marcgravia rectiflora Bejuco de palma (vine)
-Mp - Miconia prasina Camasey senisosa
-Mt - Miconia tetrandra Camasey prieto
Nv - Neorudolphia volubilis Bejuco de violeta (vine)
Nmem-Nectrandra membranacea Laurel prieto
Ok - Ormosia krugii Palo de matos
Ol - Ocotea leucoxylon Laurel geo
Om - Ocotea moschata Nemoca o Nuez moscada
Op - Ocotea portoricensis Laurel de paloma
Os - Ocotea spathulata Nemocaó o Nemocá
-Pa - Piper amalago Juiguillo oloroso
Pb - Psychotria berteriana Palo de cachimbo blanco
Pk - Philodendron krebsii Bejuco de calabazón (vine)
Pl - Philodendron lingulatum otro B. de calabazón
Pr - Palicourea riparia Cachimbo colorado
Pp - Paullinia pinnata Bejuco de cabra
-Pt - Piper treleaseanum Juguillo apestoso
Rc - Rajania cordata Bejuco de guáyaro (vine)
Rg - Rourea glabra Bejuco de Juan Caliente (vine)
Sb - Sloanea berteriana Cacao motillo o Motillo
Sc - Smilax coriacea Bejuco escambrón (vine)
Sl - Sapium laurocerasus Manzanillo
Sp - Schlegelia brachyantha (S. portoricensis) Bejuco de trapo (vine)
Tb - Tetramogastris balsamifera Palo de masa
Th - Tabebuia pallida (T. heterophylla) Roble blanco
(Ao) Tp-Trichilia pallida Gaeta (Allophylus occidentalis)
Ub - Urera baccifera Ortiga
(Pp) Wp- Wallenia pendula (Petesioides pendula) otro Ausubón
Mre- Myrcia sp. - Rojo oja menuda
Mys- Myrcia spendens (Sw.) DC. Oja menuda
Dh - Gonzalagunia hirsuta (Jacq.) Schum (synonym Duggenia hirsuta (Jacq.) Britton

R.F. Smith

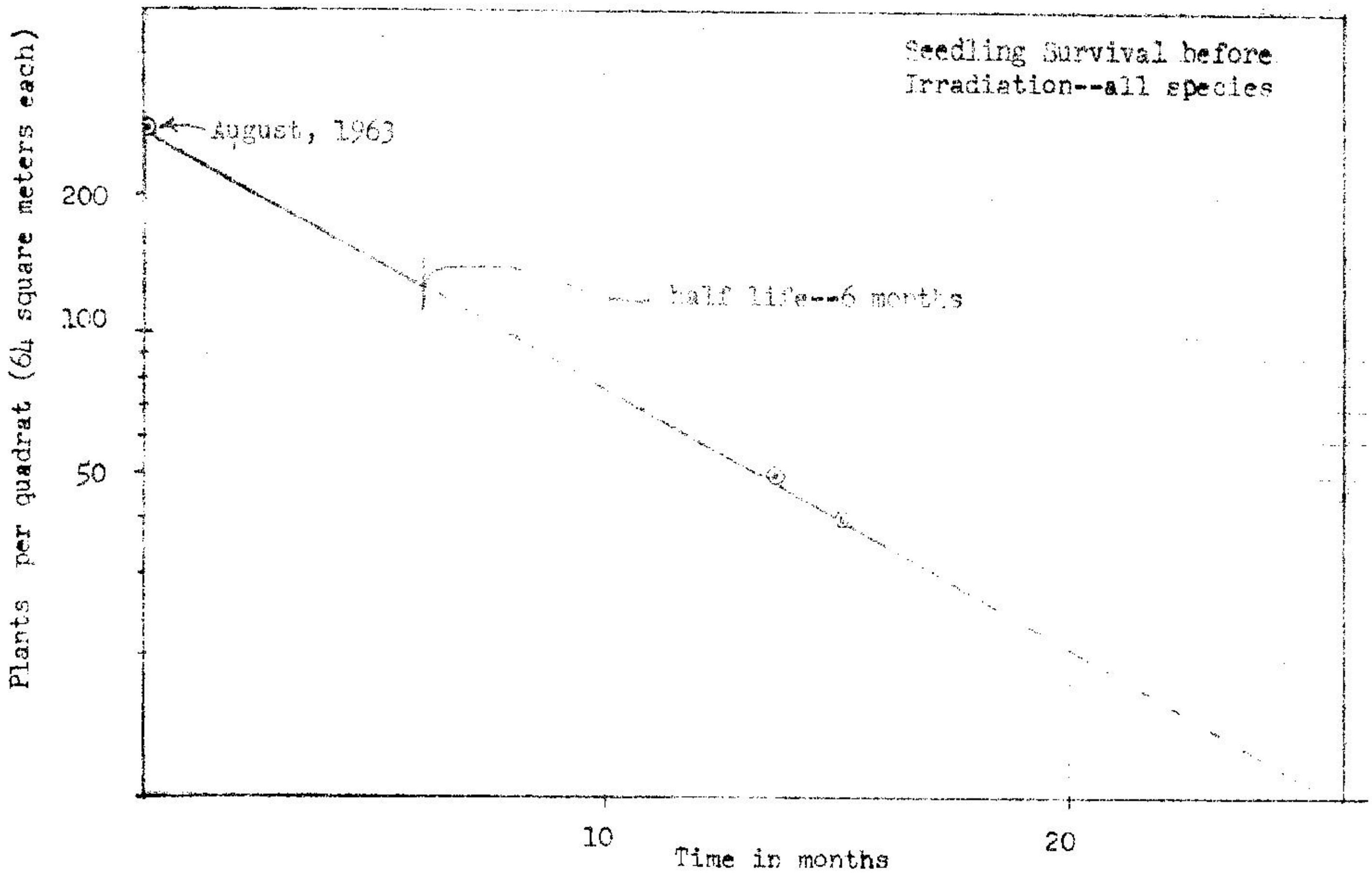


Fig. 1 Survival of seedlings in the pre-irradiation year

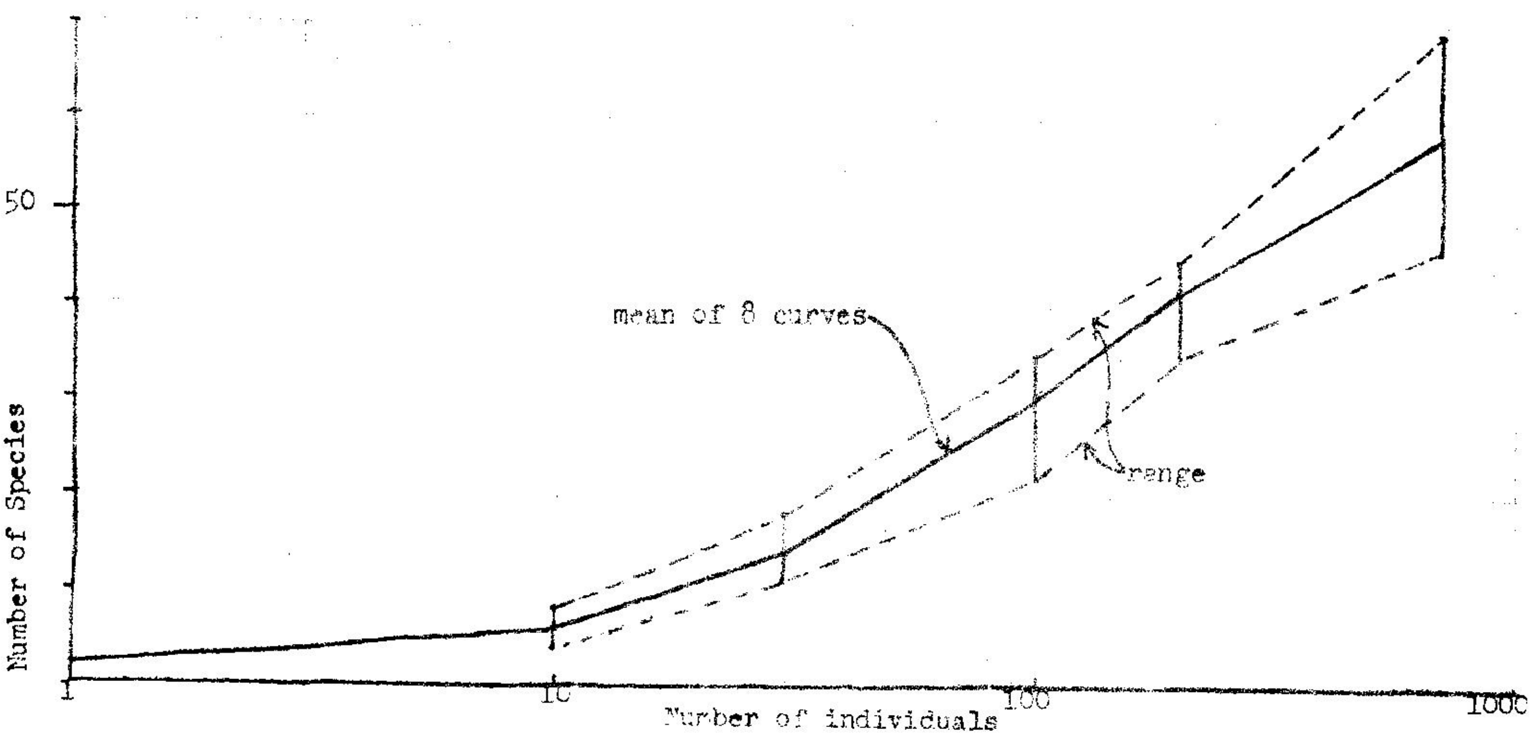


Fig. 3. Species--individual graph of diversity. plants over 12 inches.

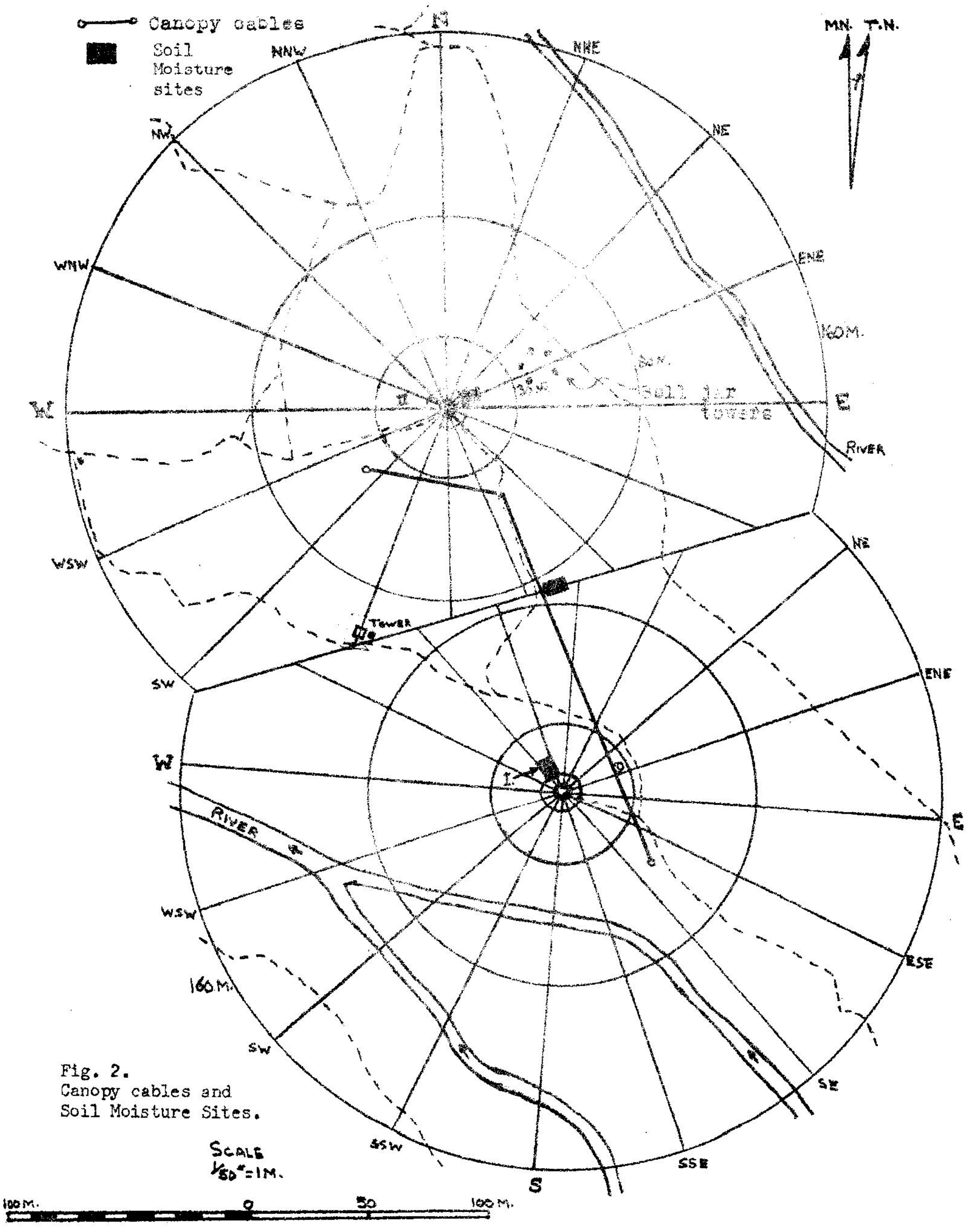


Fig. 2.
Canopy cables and
Soil Moisture Sites.

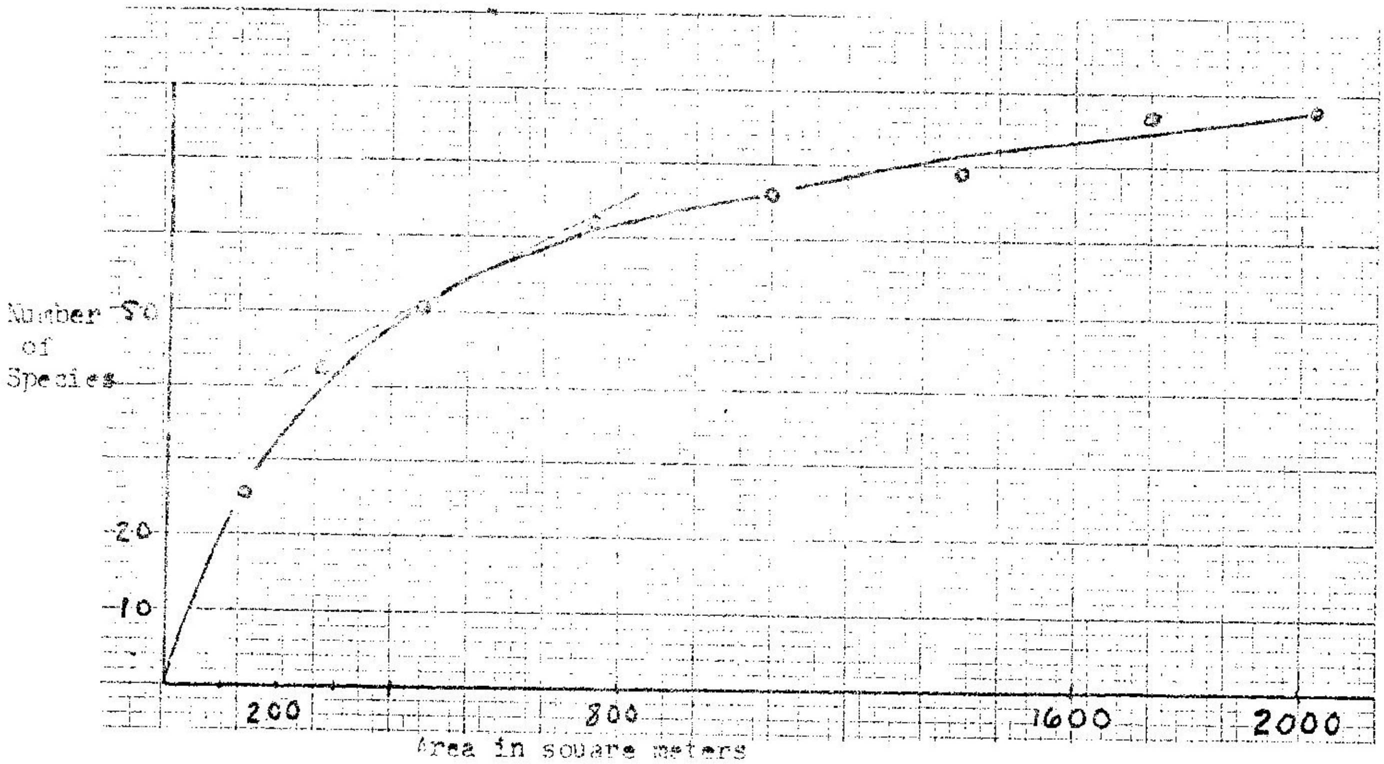


Fig. 4. Species--area curve for understory species. Radiation center only; trees 140 cm high to 10 cm DBH; area between 3.2 and 30 meter perimeter circles; data include 1357 individuals.

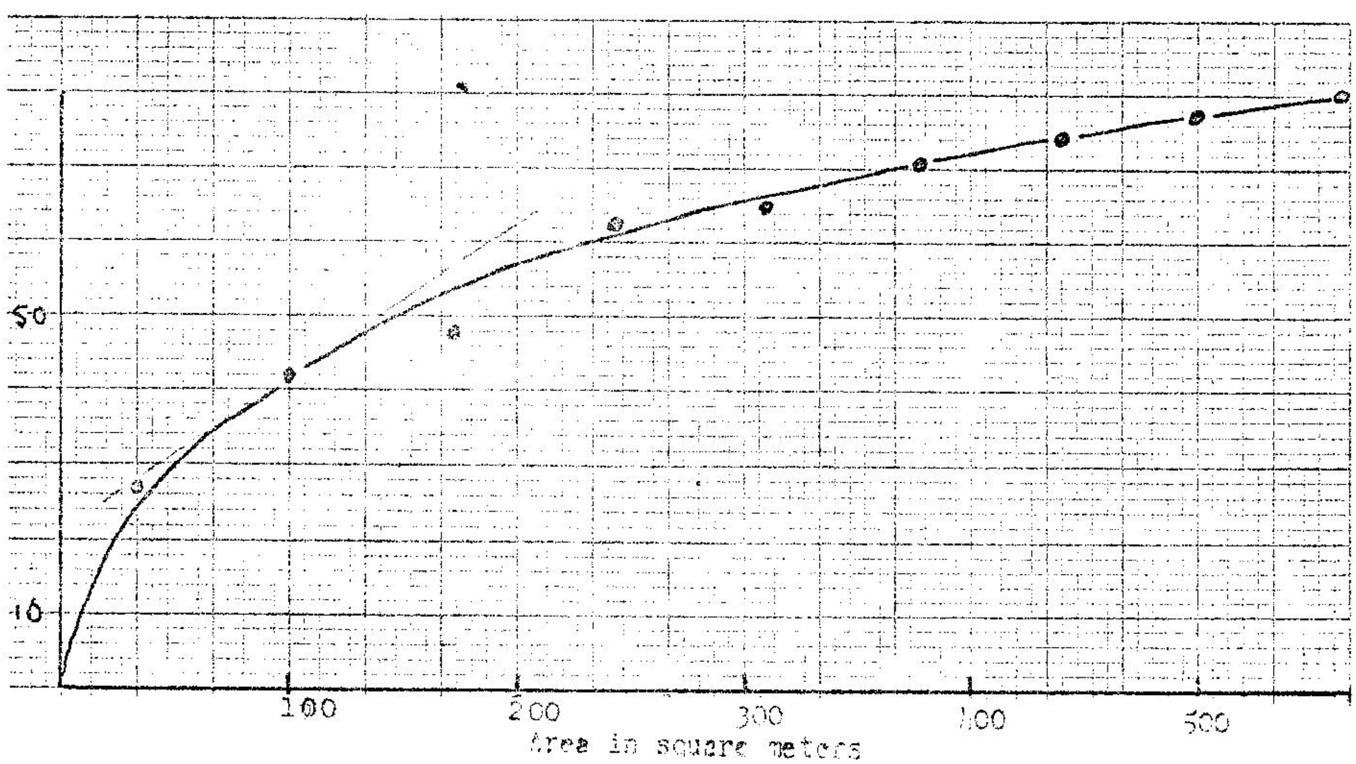


Fig. 5. Species--area curve for saplings only. Radiation center only; plants 30 to 140 cm high.

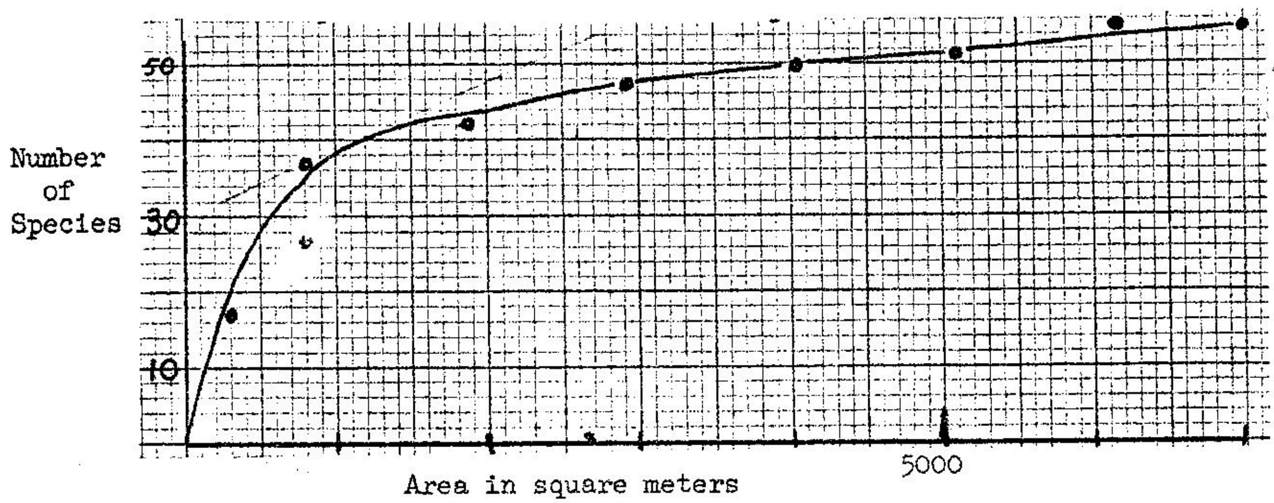


Fig. 6A. Species-area curve for canopy trees. Radiation center; plants 10 cm DBH and over; 725 individuals considered.

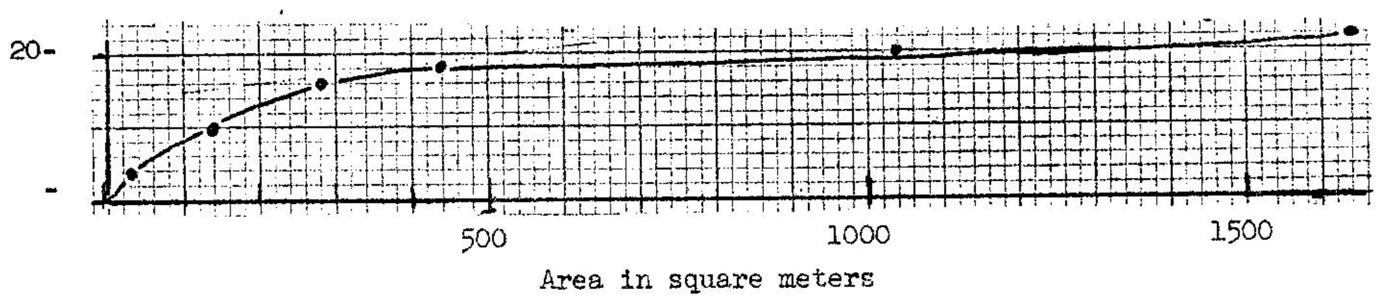


Fig. 6B. Species-area curve for lianes. Radiation center; individuals whose stem enters the crown; 230 individuals considered in an area with 156 trees.

	Radiation Center (II)	I & II Combined	N Control Center (III)	Palm area	S Control Center (I)
	43.4%		45.5%	47.1%	46.3%
	42.7		43.[illegible]	45.4	47.5
	43.3		45.0	49.8	49.2
	38.8		4[illegible].6	40.9	43.9
	43.9		[illegible]	44.[illegible]	51.5
	41.0		4[illegible].5	43.5	48.0
	42.9		40.7	44.7	45.5
	39.2		4[illegible].7	42.6	46.2
	39.1		[illegible]	41.0	40.8
	41.7		42.[illegible]	40.7	46.8
	42.6		44.4	46.[illegible]	
	39.8		45.9	47.4	
	45.2		47.2	53.7	
	41.3		47.0	45.0	
	40.1		46.0	45.6	
	40.2		47.3	49.7	
	53.7		46.3	42.2	
	43.0		47.1	53.0	
	44.6		46.5	54.1	
	38.4		48.6	48.5	
MEAN	42.3		45.7	46.7	47.1

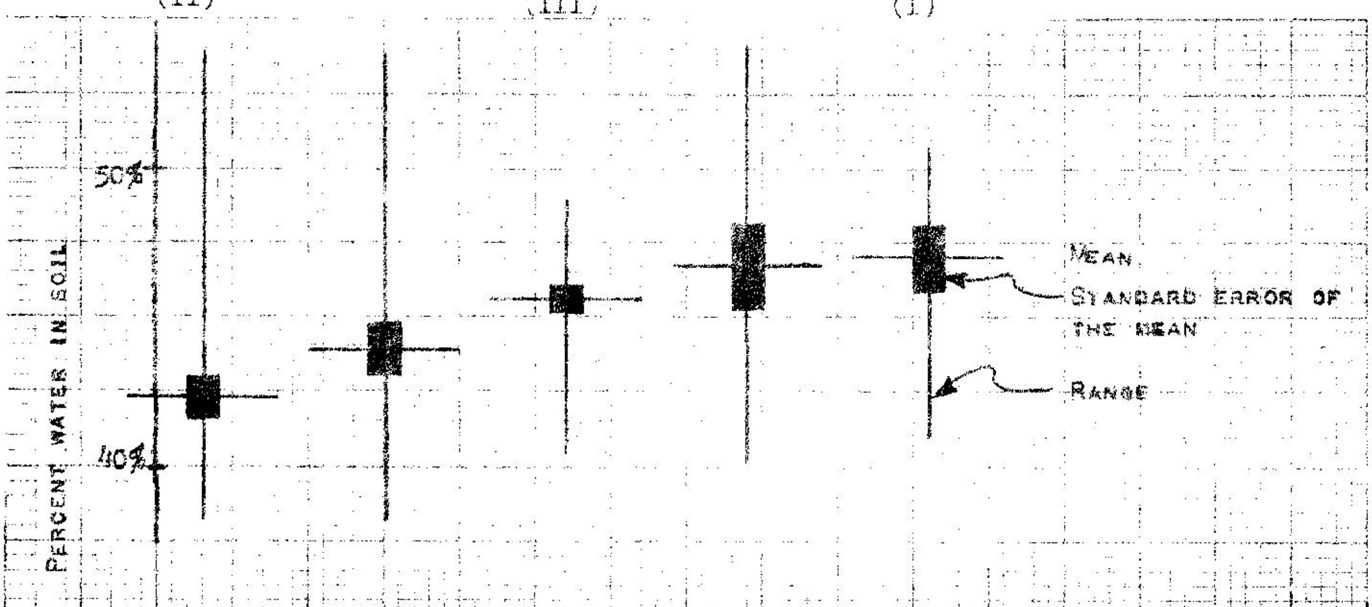


Fig. 7. Moisture in soil sampled after 3 days without rain.

Progress Report on Seedling Metabolism

By
Ariel Lugo

The present report includes results obtained in the study of two fast growing plant species adapted to successional situations at high light intensities, Anthocephalus cadamba, an imported tree from rainforests of Asia, and Cecropia peltata, a tree found in openings in the Rain Forest. A. cadamba is being tested for plantation planting near the El Verde site. Data on climax species are being proccessed.

The seedlings were studied using a Beckman Infra-red CO_2 Analyzer Model IR-15A and an open system shown in Fig. 1. They were watered before measurements and leaf area was determined after the measurement. Results were expressed in grams of carbon/leaf area/hour.

Since the seedlings were in plastic bags during measurements, the flow rate of air was adjusted to prevent abnormal effects such as overheating in plant tissues. The effects of air velocity on the metabolism were studied and results are found in Fig. 2 and 3. The rate of flow of 10 liters per minute was selected as the most suitable for high light intensity measurements.

Table 1 has some temperature measurements taken with flat thermisters probes clamped on the leaves and recorded on a Rustrak Recorder. For the Cecropia seedling the temperature under high light intensity conditions and 10 liters per minute is only 1 degree greater then the control plant out of the chamber. If the flow is decreased, the differences are then greater. Continuous temperature determinations were made on A. cadamba seedlings, and the results show a similar pattern of temperature variation in air and plant with a difference of 2 or 3 degrees, greater in the seedlings. These results show the effect of using a plastic bag as a chamber and a flow of 10 L/min.

Fig. 4 demonstrates the changes in photosynthesis in relation to light intensity in both species. In C. peltata where data are more complete, the pattern is similar to the typical curve that has been described for light adapted plants. At high intensities the species is able to maintain a more or less constant rate of production.

SPECIES	CONDITIONS	TEMPERATURE	AIR TEMPERATURE
Cecropia peltata	Low light intensity [illegible] 10 liters/minute	[illegible]°C	31°C
	[illegible]	[illegible]°C	31°C
	Same conditions [illegible]	[illegible]	31°C
	Same conditions 7.5 liters per minute	35.0°C	31°C
	Control plant	34.0°C	31°C
Anthocephalus cadamba	Morning Natural conditions	25-33°C	Similar
	Noon Natural conditions	35°C	Similar
	Night Natural conditions	23-25°C	Similar

Table I Temperature measurements taken with flat stainless steel probes clamped to the leaves and recorded on a Rustrak temperature recorder.

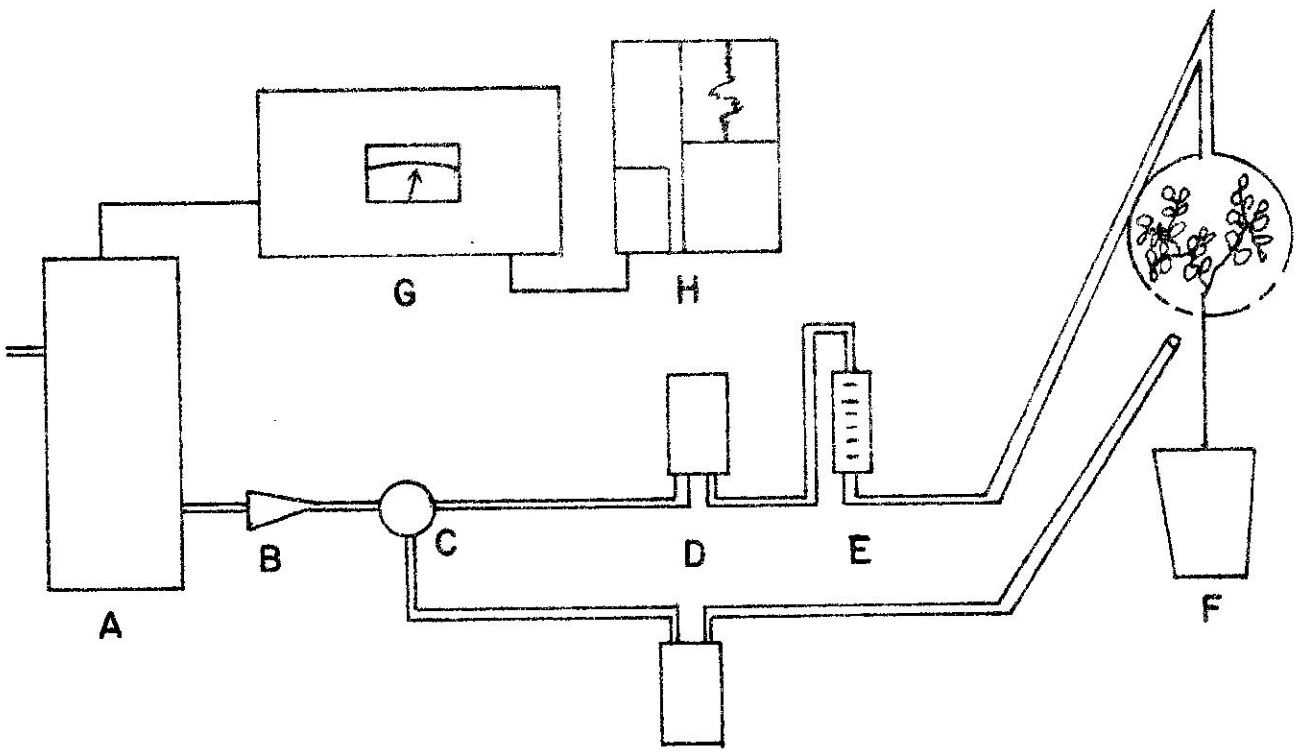


FIGURE 1 OPEN SYSTEM USED IN THE MEASUREMENT OF METABOLISM. A– INFRARED GAS ANALYZER. B– FILTER. C– THREE WAY VALVE. D– AIR PUMPS. E– FLOW METER. F– SEEDLING IN A PLASTIC BAG CHAMBER. G– AMPLIFIER. H– PONTENTIOMETRIC RECORDER.

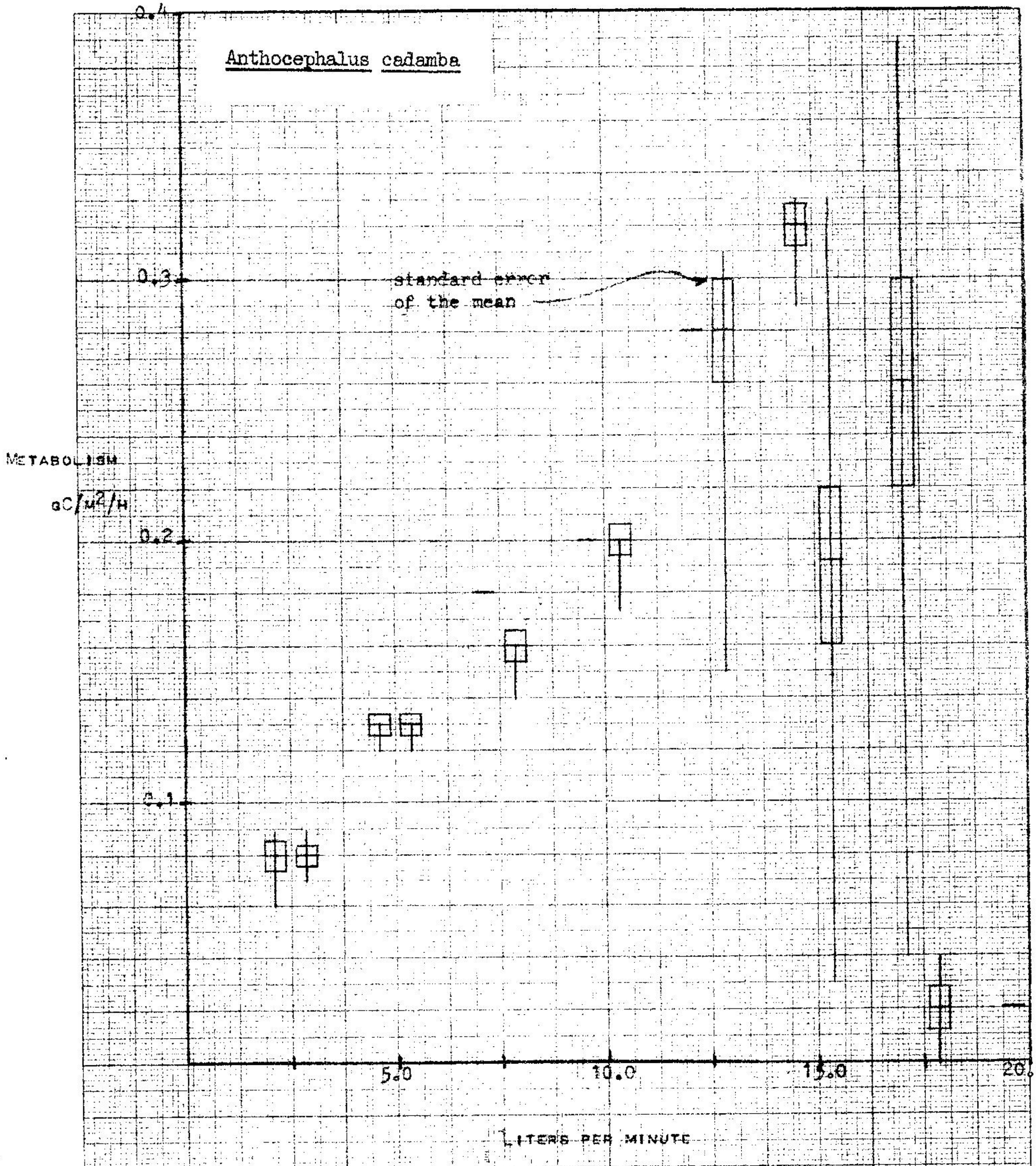


Fig. 2. Photosynthetic rate as a function of air velocity in plastic bags over leaves of *Anthocephalus cadamba* seedlings.

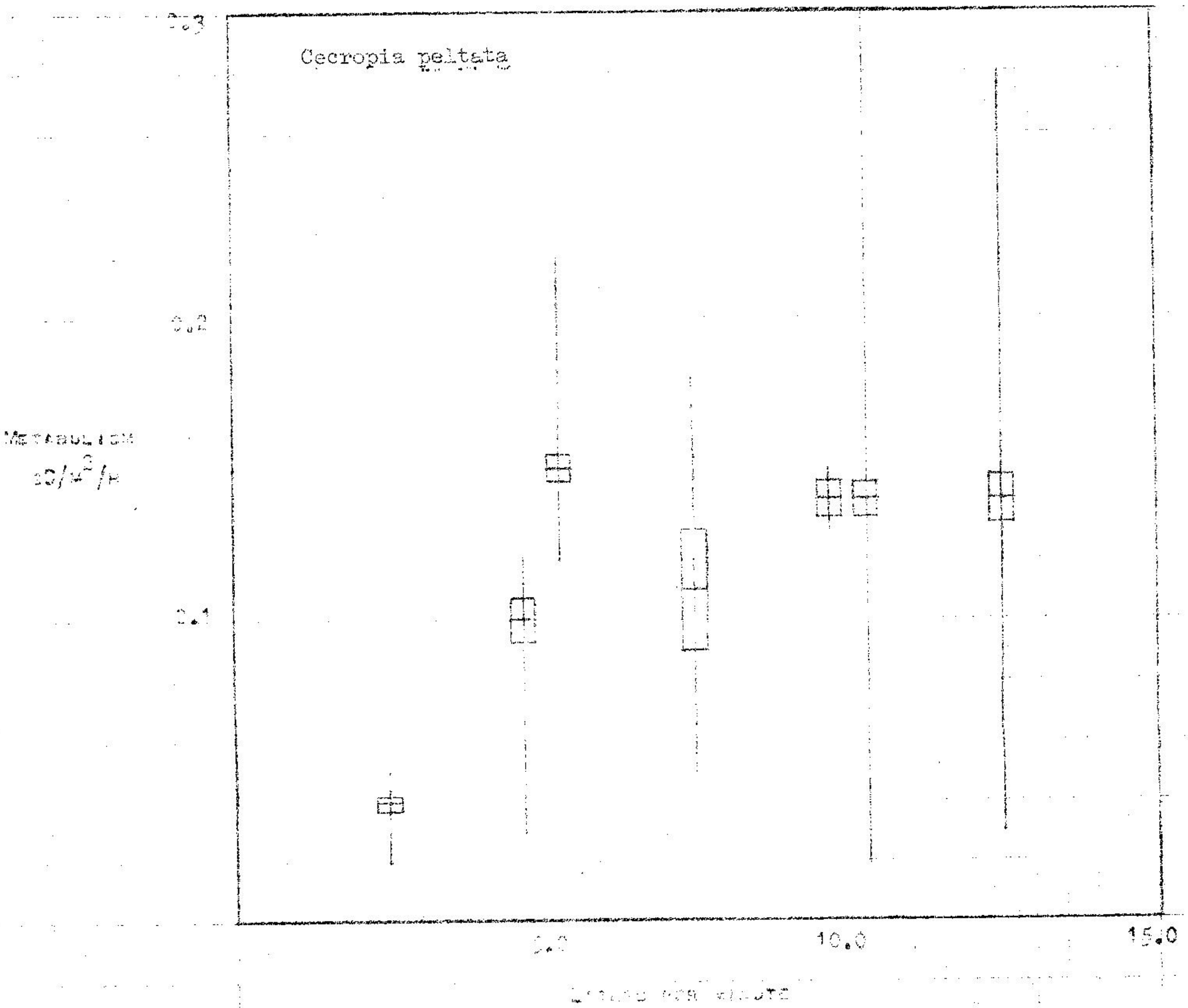
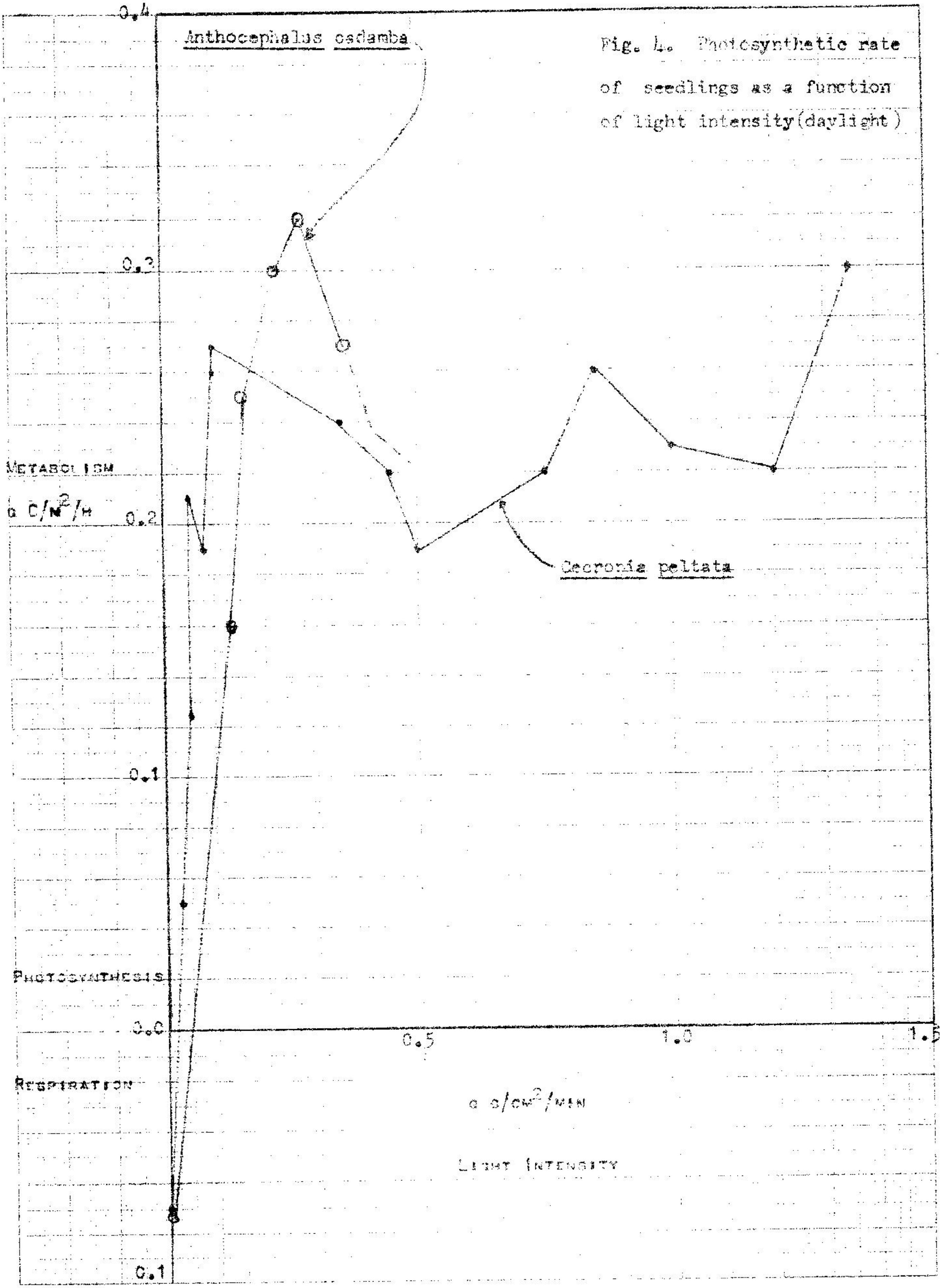


Fig. 3. Photosynthetic rate as a function of air velocity in plastic bags over leaves of *Cecropia peltata* seedlings.


0.4
Anthocephalus cadamba
Fig. 4. Photosynthetic rate
of seedlings as a function
of light intensity(daylight)
0.3
METABOLISM
G C/M²/H
0.2
Cecropia peltata
0.1
PHOTOSYNTHESIS
0.0
0.5
1.0
1.5
RESPIRATION
G S/CM²/MIN
LIGHT INTENSITY
0.1

Progress Report

By

J. Frank McCormick, University of North Carolina,
Department of Botany, Chapel Hill and The University of
Georgia Institute of Radiation Ecology.

Radiation Dosimetry of a Montane Rain Forest

Analysis of the ecological effects of ionizing radiations upon natural ecosystems requires accurate determination of the radiation doses to which individual populations and organisms are exposed. Initial studies of this type by Cowan and Platt (1)demonstrated the complexities involved in monitoring environmental radiation on a scale appropriate to ecological investigations. Subsequent studies by Cowan and Meinhold (2) discussed the differences between theoretical dose rates and those measured in air or in a forest. Recent studies by McCormick and Golley (3) demostrated microhabitat variations in dose rates and variations in the vertical distribution of exposure doses in a forest community. These data were compared with those obtained during irradiation of an old field with the same 9,200 Curie portable Cs 137 source.

In this study a total of 1000 Con-Rad lithium fluoride S-7 thermoluminescent dosimeters and 250 lithium fluoride microdosimeters were placed in the rain forest to monitor exposure doses to plants and animals. Following irradiation the S-7 dosimeters will be processed by the University of Puerto Rico Nuclear Center. The radiology laboratory retained fifteen S-7 dosimeters in order to prepare a calibration curve for the Cs 137 source. All microdosimeters will be returned to the manufacturer for processing. Two hundred of these were placed in small animals under the direction of Dr. Fred Turner. The remaining fifty were placed in the forest with S-7 dosimeters in order to compare their sensitivities.

Maps have been prepared in duplicate which indicate the location of every dosimeter in the forest. The maps also list the dosimeters by code to identify the phase of the study to which they are relevant.

Keeping in mind the problems and results discussed in previous studies and upon estimation of the requirements of the numerous investigations, the rain forest dosimetry program includes seven major phases: (1) A symetrical grid of dosimeters in the experimental and control areas from which isodose lines can be prepared; (2) A series of dosimeters at varying elevations (4" in the soil, ground level, 1 1/2 meters, 3 meters, 6 meters, and 9 meters) at most of the points on the grid in order to estimate the vertical distribution of dose. Although it is desirable to place dosimeters at elevations above 9 meters in a few locations in the forest, the scope of the study was limited by the investigator's ability to ascend higher into the canopy without fear of descending at a rate exceeding his limits of a physical tolerance. (3) A series of dosimeters on the front and rear sides of trees at each of the elevations listed previously in order to determine the shielding effects of individual tree trunks of various species and diameters. These were located at most of the points on the grid. Dosimeters were placed on the front and rear side of an additional 100 trees scattered throughout the lower center in order to meet the need of a forest tree growth study being conducted by Peter Murphy; (4) Several hundred dosimeters were placed in microhabitats to determine the shielding effects of vegetation, rocks, or terrain upon seedlings or seeds. These dosimeters were distributed in pairs, one being placed behind a potential shield at ground level and the other near-by within line of sight of the irradiator. One hundred of these locations coincide with 1 x 1 meter quadrats which are being analyzed in terms of seedling density, diversity, distribution, and growth. The remaining sites were selected on the basis of visible inspection and upon evaluation of maps prepared by the U.S. Corps of Engineers; (5) A series of dosimeters at 1 1/2 meter elevation encircling the 10 meter and 30 meter perimeters which enclose the anticipated "zone of biological effects". These dosiemters were placed in groups of 2 or 5, and included both Con-Rad TLD S-7 and microdosimeters in order to compare the sensitivities of the two types and to estimate variability between sensitivities of individual dosimeters in the forest; (6) Dosimeters at several points on the public road, at entrance gates, and along the rivers where the public has closest access to the areas or where people frequently congregate for "recreational" activities; (7) Consultation and placement of dosimeters for special requirements of individual investigators.

Dosimeters placed to meet the requirements of one phase of the study frequently coincide with or occur near dosimeters designed to satisfy other phases of the study. These replications are of value in estimating variability and reduce the chance of losing important data due to the loss of a dosimeter. A code system has been developed to describe the location of each dosimeter when they are harvested at the end of the radiation period. When a single dosimeter is relevant to more than one phase of the study, code numbers for each phase will be listed. By cross-listing dosimeters in this manner approximately one hundred replications will be gained for estimation of dosimeter variability.

The Tropical Terrain Research Detachment of the U. S. Army Corps of Engineers Waterways Experiment Station assisted in the difficult job of placing dosimeters in the forest.

References Cited

1. Cowan, J. J. and R. B. Platt. Radiation dosages in the vicinity of an unshielded nuclear reactor. Radioecology 311-318. Reinhold Pub. Co. New. York, (1963).

2. Cowan, F. P. and C. B. Meinhold. Radiation dosimetry for Co^{60} and Cs^{137} gamma ray field irradiation facilities. Rad. Bot. Vol. 2, 241-250, (1962).

3. McCormick, J. F. and F. B. Golley, Irradiation of natural vegetation, experimental facilities, procedures, and dosimetry. (in preparation).

Studies of Forest Seedlings

Studies of forest seedlings were initiated with objectives of: (1) determining the density, distribution, and diversity of seedlings in the experimental and control centers of the rain forest; (2) analyzing the direct and indirect effects of ionizing radiation upon forest seedlings in terms of the above listed criteria; (3) determining the extent to which seedlings contribute to recovery of the irradiated forest; and (4) a related objective of determining the extent to which small seedlings are shielded from irradiation by vegetation, rocks, and terrain.

In order to acquire the data necessary to fulfill these objectives approximately fifty permanent 1 x 1 meter plots were established in each of the two centers. These plots were located in pairs along transects running from 10 m to 30 m on four compass bearings which included mild and severe up-slopes and down-slopes. Additional transects run from 30 m to 80 m along two compass bearings, one going up hill and the other downhill from the center. One of the paired plots is behind a potential radiation shield (vegetation, rocks, terrain) while the other is in approximate line-of-sight of the irradiation source.

Initial results of this study are presented in Table I and Figure I.

In order to later distinguish between the direct effects of ionizing radiation and the indirect effects due to changes in the microenvironment of the seedlings,measurements were made of light intensity, relative humidity, and temperature, 3 m, 1 m, ground level, plus soil and litter temperatures at most of the 100 plots. These instantaneous readings provide data which describe the strength of vertical gradients through the seedling layer of the forest. These data are supplemented by 24 hour recordings of temperature and humidity in one tenth of the plots. These data are further supplemented by constant temperature recordings of 1 week duration in one location along each of the four 10 m - 30 m transects and by environmental data monitored continuously from environmental tower in the forest.

These investigations will be repeated at appropriate time intervals following irradiation in order to describe the effects of radiation upon forest seedlings, the recovery of seedling populations, and the contribution of seedling populations to community recovery.

Whenever possible, radiation tolerances of seedlings will be compared, with tolerances predicted on the basis of nuclear volume. When appropriate, laboratory studies of seedling tolerances and radiation and other stresses will be conducted in order to distinguish between the direct effects of radiation and the indirect effects of microenvironmental change upon seedling survivial. Limits of tolerance observed in the laboratory will be compared with limits of environmental variability in the forest before and after radiation.

Euterpe globosa Populations

Although the rain forest is noted for the extremely high diversity, the *Euterpe* palm comprises one fourth of the vegetation. For this reason the palm serves as a good species for autecological studies and evaluation of radiation effects upon tree populations.

In four of the 16 sectors from the center of the study area to 30 m all palms were counted, measured, and mapped. Similar data were recorded for transects from 30 m to 80 m in two of these 16 sectors. These data were collected in both the experimental and control centers. These studies of palm populations will be repeated following irradiation.

Results thus far indicate a 95% mortality rate for young seedlings, a 12% mortality rate for established seedlings and 64% mortality rate for shrub size plants. Approximately 1.6% of the palm seedlings survive to become trees of the sub canopy or canopy. Those trees which do survive make up 1 out of every 4 trees in the forest according to Wadsworth.

Observations of palm phenology indicate that the trees fruit and flower at any and all times of the year.

Estimates of palm biomass, productivity,growth requirements, and radiation sensitivity are yet to be conducted.

The following data are for the forest seedling study. There were 51 plots in the upper center and 52 plots in the lower. Each of the 103 plots was 1 m^2. Density is individuals per m^2 and % frequency is the % of the plots in which a species occurred.

The mean number of species per m^2 is:

Upper Center	Lower Center	Total
4.88	5.86	5.38

The mean number of individuals per m^2 is:

Upper Center	Lower Center	Total
11.43	13.81	12.63

Diversity determined as species/individuals is:

.427	.424	.426

The data for the two centers seem to be quite comparable. This is gratifying since Alejo counted most of the plots in the upper center and I did most of those in the lower center.

Additional size class data were obtained for <u>Euterpe</u>. Both the m^2 quadrats and transects were used. The data were quite comparable for each method. I grouped the plants into 4 classes; seedlings, established seedlongs, shrubs, and trees. The data have been converted to % mortality of a particular age class and are as follows:

Seedling mortality	95%
Established seedlings	12%
Shrubs	64%

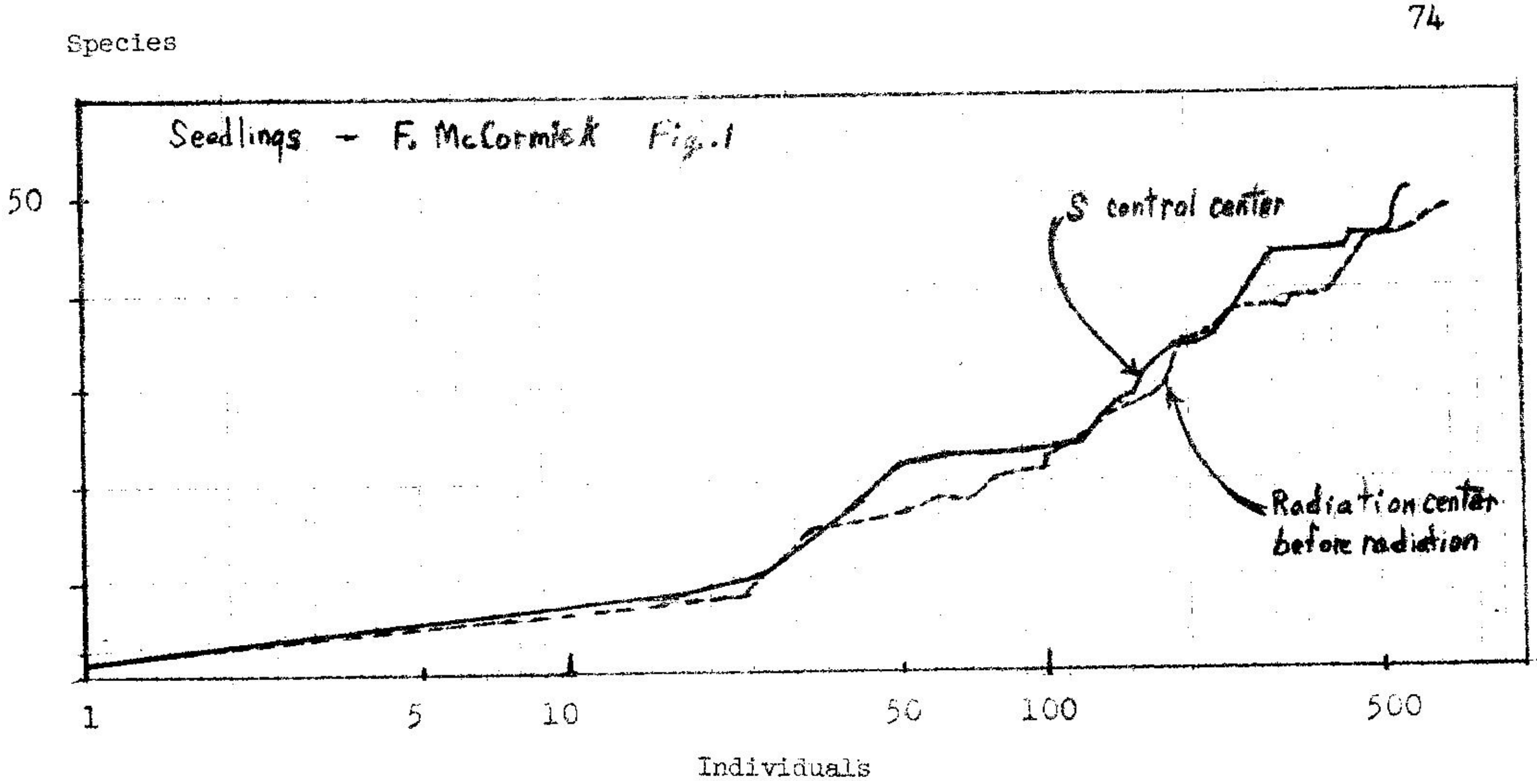
Thus, only 1.6% of the seedlings survive to the tree stage.

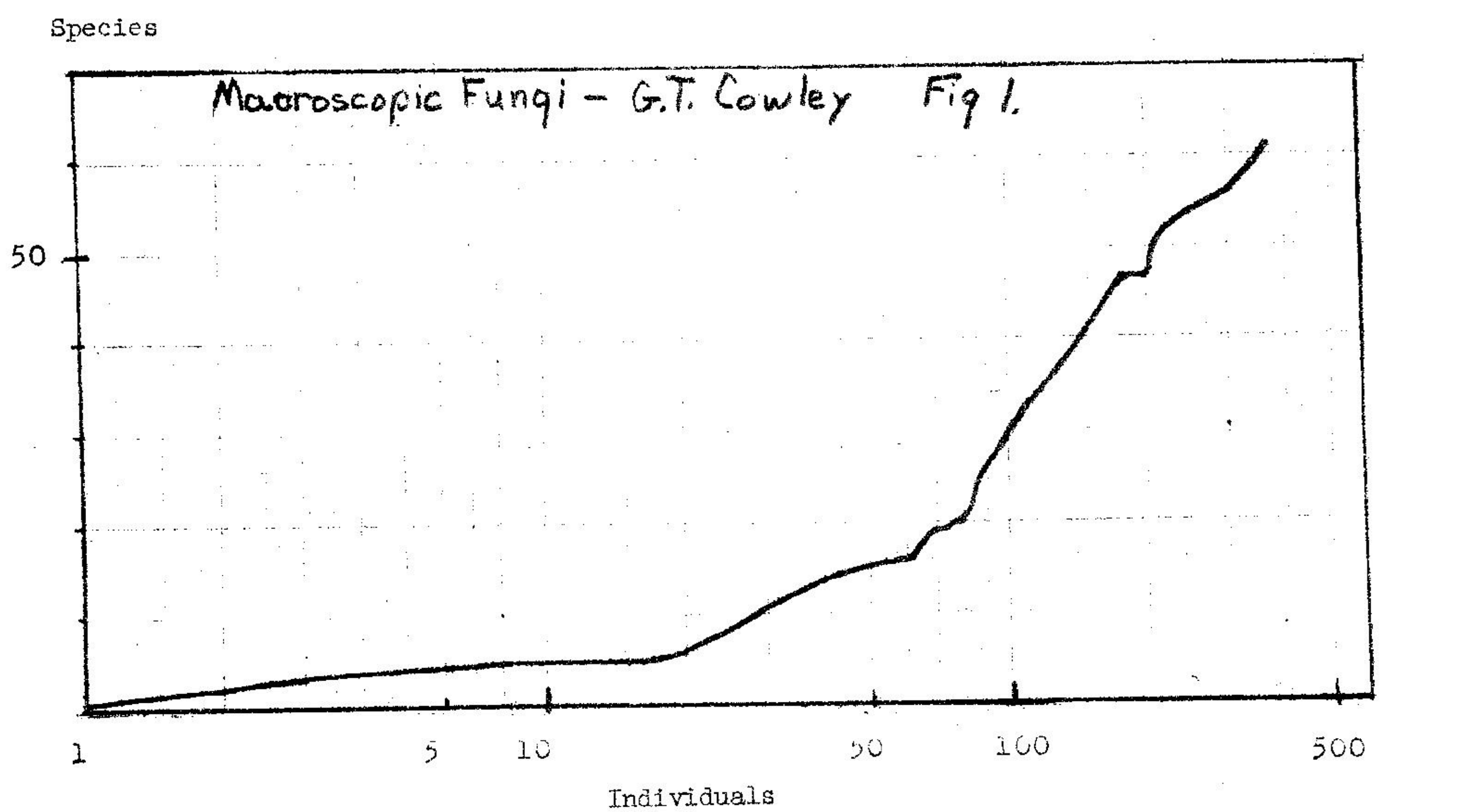
Table 1.

Forest Seedlings

Species	Density m^2 Upper	Density m^2 Lower	Density m^2 Total	Percent Frequency Upper	Percent Frequency Lower	Percent Frequency Total
Eg - Euterpe globosa	1.66	3.71	2.62	45	86	66
Am	.04	0	.02	2	0	0
Pomarosa	0	.52	.26	0	11	6
Es - Eugenia stahlii-Guayabota	1.33	.33	.83	47	23	35
Ab - Alsophila borinquena-Palmilla grande	.29	.10	.19	20	8	14
Al - Alchornia latifolia - Achotillo	0	0	0	0	0	0
Tp - Trichilia pallida - Gaeta	.04	.11	.08	4	11	8
Ap - Alchorneopsis portoricensis-Palo de pollo	.12	0	.06	6	0	3
Bc - Buchenavia capitata - Granadillo	0	.02	.01	0	2	1
Bl - Banisteria laurifolia-Bejuco sonadora	.20	.25	.22	10	17	14
Bs - Byrsonima spicata-Maricao colorado	.02	0	.01	2	0	1
Ca - Casearia arborea- Rabo de ratón	.02	.04	.03	2	4	3
Cc - Guatteria caribaea - Ilán-ilán	0	0	0	0	0	0
Cep- Cecropia peltata-Grayuma hembra	0	0	0	0	0	0
Cg - Casearia guianensis-Otro palo blanco	0	0	0	0	0	0
Clg- Clusia gundlachii - Cupey	0	0	0	0	0	0
Cp - Croton poecilanthus - Sabinon	.02	.13	.08	2	10	6
Cpa- Cassipourea alba - Teta de burra	0	.08	.04	0	8	4
Cr - Cyrilla racemiflora - Palo colorado	0	0	0	0	0	0
Cs - Casearia sylvestris-Palo blanco	0	0	0	0	0	0
Csl- Cordia sulcata - Morral	0	0	0	0	0	0
Css- Doliocarpus calinoides	.20	0	.10	2	0	1
Cv - Chione venosa	0	0	0	0	0	0
De - Dacryodes excelsa - Tabonuco	.27	.38	.33	24	25	24
Dg - Drypetes glauca - Cafeillo	.86	.60	.73	25	36	31
Dh - Duggena hirsuta	0	0	0	0	0	0
Dd - Dryopteris deltordea- Palmilla pequeña	.55	.42	.48	27	29	28
Dp - Daphnopsis phillippiana - Majagua de sierra	0	0	0	0	0	0
Ej - Eugenia jambosa	0	0	0	0	0	0
Ev - Elsata virgata - Bejuco de Añen	.08	.75	.42	4	33	18
Fi - Ficus laevigata - Colorado	0	.02	.01	0	2	1
Gg - Guarea sp.	.39	.73	.56	25	33	29
Cl - Guttarda laevis - Cucubano	0	0	0	0	0	0
Hf - Henrietta fasciculata	0	0	0	0	0	0
Hor- Homalium racemosum-Caracolillo	.02	.06	.04	2	4	3
Hr.- Hirtella rugosa - Teta de burra	.18	.02	.10	12	2	7
If - Ixora ferrea - Palo de clavo	0	.04	.02	0	4	2
Il - Inga laurina - Guamas	.61	1.71	1.16	16	25	20
Iv - Inga vera - Guava	.02	.60	.31	2	20	11

Species	Density m² Upper	Density m² Lower	Density m² Total	Percent Frequency Upper	Percent Frequency Lower	Percent Frequency Total
Mgs- Magnolia splendens-Laurel sabino	0	0	0	0	0	0
Md - Matayba domingensis - Negralora	.55	.38	.47	23	15	19
Mg - Micropholis garciniaefolia-Caimètillo verde	.02	0	.01	2	0	1
Mh - Meliosma herberti - Aguacatillo	.02	.02	.02	2	2	2
Mn - Manilkara nitida - Ausubo	.08	.13	.11	8	13	11
Mr - Marcgravia rectiflora-Bejuco de Palma	0	.02	.01	0	2	1
Mt- Miconia tetandra-Camasei (Prieto)	.02	.02	.02	2	2	2
Nv - Neorudolphia volubilis _Bejuco de violeta	0	0	0	0	0	0
Ok - Ormosia krugii - Palo mato	.25	.06	.16	20	4	12
Ol - Ocotea leucoxylon-Laurel geo	.12	.02	.07	12	2	7
Om - Ocotea moschato - Nemoca	.02	.16	.09	2	14	8
Op - Ocotea portoricensis - Laurel prieto	.04	.02	.03	4	2	3
Pb - Psychotria berteriana-Palo de cachimbo blanco	.04		0	2	0	1
Pk - Philodendron krebsii-Bejuco de calabazón	0	.04	.02	0	4	2
Pl - Philodendron lingulatum	0	0	0	0	0	0
Pr - Palicourea reparia -Cachimbo colorado	.06	.29	.17	4	21	13
Pp -Paullinia pinnata-Bejuco de cabra	.02	0	.01	2	0	0
Rc - Rajania cordata-Guayaro	0	0	0	0	0	0
Rg - Rourea glabra-Bejuco de Juan Caliente	.92	.10	.50	29	1	15
Sb - Sloanea berteriana-Cacao mortilla	.65	.69	.67	16	38	27
Sc - Smilax coriacea-Bejuco escambrón	.10	.11	.11	6	4	5
Sp - Skelegelia portoricensis-Bejuco de trapos	0	0	0	0	0	0
Tb - Tetramogastris balsamifera-Palo de Masa	.12	.08	.06	4	8	6
Th - Tabebuia heterophylla - Roble blanco	.02	.06	.04	2	6	4
Cb - Cordia boringensis	.10	.08	.09	10	6	8
Mp -	.14	.02	.08	12	2	7
Dm - Didymomanax	.18	0	.09	8	0	4
Da -	.02	0	.01	2	0	1
Am -	.08	0	.04	2	0	1
Ms -	.06	.04	.05	6	2	4
Caliente	0	.30	.15	0	16	8
Pt - Piper-treleaseanum	0	.38	.19	0	32	16
Pa -	.06	0	.03	4	0	2
Hueso blanco	.24	.02	.13	10	2	6
E -	.02	0	.01	2	0	1
As -	.06	0	.03	2	0	1
Mb -	.02	0	.01	2	0	1
Lam	.24	0	.12	6	0	3
Pan	.06	0	.03	2	0	1
Si - Mato e payo	0	.06	.03	0	4	2
Palo Guara guao	0	.02	.01	0	2	1
Byrsonima - Bs-sp	0	.02	.01	0	2	1
Laurel amarias	0	.02	.01	0	2	1
Carratos	0	.02	.01	0	2	1


Species
Seedlings - F. McCormick Fig. 1
50
S control center
Radiation center before radiation
1
5
10
50
100
500
Individuals


Species
Macroscopic Fungi - G.T. Cowley Fig 1.
50
1
5
10
50
100
500
Individuals

A SURVEY OF THE FLESHY FUNGI

G. T. Cowley
University of South Carolina

In late July and early August, 1964, a survey of all detectable fungus fruiting bodies within a 10 meter radius and out to 30 meters in four sectors (N-NNE, E-ESE, S-SSW, W-WNW) in both study centers was made. Thus a total area of 917.48 square meters was sampled in each center. All detectable fruiting bodies were counted and identified as nearly as possible with the facilities at hand.

Three hundred sixty eight fruiting bodies representing 66 different species were detected. Twenty three of these were common to both centers, 24 were found only in the south center and 19 only in the north center (table 1).

The spatial distribution of each entity in each center was determined as follows: 1) The frequency of occurance of each species in each center was determined by calculating the percentages of marked sectors (i.e. N-NNE, NNE-NE, etc.) in which it appeared. 2) The density of each species in each center was determined by dividing the number of individuals by the number of sectors sampled. 3) Expected density was determined from a modified Fracker and Brischle table relating frequency to density (Curtis and Cottam, 1962). 4) Observed density (D) divided by expected density (d) yields a figure for the degree of aggregation. A species was considered to be aggregated if the D/d ratio was 2.00 or higher and random if below 2.00.

The majority of species were determined to be randomly distributed. Those aggregated in both centers were #'s 6,48, and 66. Those appearing in only one centers were #'s 21, 54, 59, 64, and 65 in the north center and 26, 30, 31, 35, 46, 49, and 61 in the south center. Those aggregated in the north center and random in the south center were #'s 5, 15, 43, 44, and 57 while #'s 60 and 62 were aggregated in the south center and random in the north.

Two reasons for aggregation may be recognized. First many fruiting bodies may have arisen from a single mycelium or mycelial network, and second a particular species may have had an affinity for a particular substrate type. The latter would seem to be true for species #'s 64 and 66 which were found exclusively on palm litter.

The similarity between the populations was calculated using the formula 2w/A+B X 100 (Curtis, 1959) where A is the total of the same value for the south center, B is the same value for the south center, and w is the species and frequencies in common between centers. This if the index is 100, the populations are identical, and if it is 0 the populations are totally dissimilar. The index of similarity between the populations of the two centers was exactly 50.

Figure 1 shows the diversity curve for fungi as encountered when counted by sector. See P. 74.

Litter Decomposition Fungi

A second study was initiated in the forest to determine the succession of microfungi on decaying leaves of Dacryodes excelsa, Manilkara nitida, Croton poecelanthus, Cecropia peltata, Sloanea berteriana, and Euterpe globosa. Freshly fallen litter of each of these tree species was collected and an air dried and weighed amount was put into litter bags. Two bags of each species were frozen, and 10 bags of each species were placed at 11-12 meters from the center of each study center of the forest. Duplicate bags are taken in and frozen each month until irradiation is begun. Another similar set of bags is to be placed out at the beginning of irradiation, and another immediately after. These sets will be harvested as the first.

The contents of these bags will be weighed and populations of microfungi isolated from each to attempt to correlate the fungal populations on each species with the stages of decomposition before, during and after irradiation.

Table 1. Name, location, and substrate of each fruiting body type detected.

#	Fungus	Fruiting Bodies Seen North	South	Total	Substrate
1.	Lycoperdon pusillum	11		11	a
2.	Armellaria sp.	L10	6	16	a
3.	Irpex farenaceus	1	2	3	a
4.	Auricularia sp.	6		6	a
5.	Polyporus sp.	2	1	3	a
6.	Marasmus rotula	9	10	19	b
7.	Nummularia sp.	5	1	6	a
8.	Psathyrella disseminata	2	1	3	b
9.	Flammula earlii	2		2	a
10.	Lepiota naucina	3		3	c
11.	Marasmus olneyi	11	7	18	b
12.	Entyloma sp.	4	3	7	c
13.	Polyporus sp.	1		1	a
14.	Polyporus sp.	1		1	a
15.	Crepidotus malachius	13	2	15	a-d
16.	Xylaria sp.	3	5	8	a
17.	Collybia abundans	1		1	b
18.	Poria sp.	1	1	2	a
19.	Polyporus sp.	1		1	a
20.	Collybia tenuipes	1	1	2	a
21.	Hygrophorus sp. (?)	3		3	b
22.	Crepidotus millis	1		1	a-b
23.	Collybia sp.	1		1	c
24.	Inocybe spl.	1		1	a
25.	(Agaricales)		2	2	c
26.	Tricholoma sp.		7	7	c
27.	Xylaria sp.		1	1	a

#	Fungus	Fruiting Bodies Seen North	South	Total	Substrate*
28.	Marasmus delactans		4	4	b
29.	Leptonia sp.		1	1	b
30.	(Sclerodermatales)		20	20	a
31.	(Agaricales)		19	19	a
32.	Sterium sp.		2	2	a
33.	Poria sp.		1	1	a
34.	???		1	1	a
35.	Thielephora sp.		2	2	a
36.	Stereum sp.		1	1	a
37.	Favolus braziliensis		1	1	a
38.	(Agaricales)	1	4	5	a
39.	Mycena haematops (?)	1	3	4	a
40.	Clitocybe dealbata	1	1	2	c
41.	Mutinus caninus		1	1	c
42.	Hebeloma sp.		1	1	c
43.	Mycena sp.	10	3	13	c
44.	(Agaricales)	2	7	9	c
45.	Cortinarium deceptivus		3	3	c
46.	Clavaria stricta		25	25	c
47.	Stereum sp.		1	1	c
48.	Stereum sp.	2	7	9	a
49.	Clitocybe sp.		3	3	c
50.	Schizophyllum commune		1	1	c
51.	????	1		1	c
52.	Polyporus picipes	1		1	a
53.	Stereum sp.	2	1	3	c
54.	(Agaricales)	2		2	d
55.	(Tremellales)	1		1	a
56.	Psathyra sp.		1	1	c
57.	Mycena sp.	2	1	3	d
58.	(Agaricales)		1	1	a
59.	Fomes senex	12		12	a
60.	Marasmus	1	13	14	b
61.	Mycena atroalba		2	2	c
62.	Marasmus sp.	2	8	10	b
63.	Xylaria sp.		1	1	b
64.	Marasmus sp.	3		3	b
65.	Clitocybe sp.	2		2	c
66.	Xylaria sp.	3	34	37	b

* - a. dead wood, b. litter, c. soil, d. live wood

References:

Curtis, J. T. and G. Cottam.,1962. Plant Ecology Workbook. Burgess Pub. Co.

Curtis, J. T., 1959. The Vegetation of Wisconsin, Univ. of Wis. Press.

Soil, Root Layer, and Litter Layer Microfungi

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A study of the pre-irradiation microfungal populations of the litter, root, and soil layers into the Luquillo Experimental Forest, Puerto Rico, was initiated in late July and August of 1964.

In each of the two study centers, 4 samples of soil, roots, and litter were taken at 3.2, 10, 30, and 55 meters from the center point. Serial dilutions to 1:1000 of the soil samples were made with sterile distilled water, and serial dilution to 1:10,000 of root and litter samples were made after grinding in a Waring Blendor. One ml. of each dillution was pipetted into each of 5 plates of a modified Martin's medium (Allen, 1957). The modification consisted of replacing streptomycin with lactic acid to lower the pH. of the medium to approximately 4.5 to eliminate bacterial contamination. After incubation for 3 to 4 days, colonies on the plates were conted and the total population of fungi per gram of sample were calculated for each sample. Then 30 random isolates were transferred from each sample to tubes of malt extract agar, incubated for one week, and sorted into separate entities by cultural characteristics. The number of isolates of each entity from each sample was recorded.

To isolate less abundant, but more resistant forms (particularly Ascomycetes), a portion of each sample was treated for two minutes with 65% ethyl alcohol. A small amount of this material from each sample was placed in a sterile petri dish, and warm modified Martin's medium was poured over it. After incubation for 3 to 4 days, 10 isolates were taken from each sample, with an attempt to isolate as many different forms as possible. These isolates were then treated as above.

Cultures of each entity isolated were returned to our laboratory at the Univ. of South Carolina for identification. Although there is a great deal of work yet to be done on identification, it is possible to arrange the entities for analysis from a distributional point of view.

Total populations per gram of sample as determined from the dillution plates are found in Table 1.

Populations in the three layers were quite distinct, with 45 species isolated from soil only, 40 from roots only, 41 from litter only, and 17 from 2 or more layers (Table II). These 143 entities represent 1448 isolates.

A determination of the index of similarity (Curtis, 1959) between layers and centers further demostrates the difference between populations in the three layers and similarity between the same layers in the different centers (Table III).

A similar treatment of the alcohol treated samples showed similar results (Tables IV and V). These cultures have been kept separate from those of the dilution plates, however, it will undoubtedly be found that some of the species are the same in the two groups.

These studies will be followed by similar post-irradiation studies to detect changes in the populations induced by irradiation either directly on indirectly.

References:

Allen O.N 1957. A Laboratory Manual for Soil Microbiology. Burgess Publishing Co., Minneapolis.

Curtis, J. T. 1959. The Vegetation of Wisconsin. The Univ. of Wis. Press, Madison, Wis.

Table I. Range of populations of fungi per gram in samples taken from soil, roots, and litter in each study center.

Center	Layer		
	Soil	Roots	Litter
North			
Min.	2×10^3	1.6×10^5	1×10^5
Max.	85×10^3	11.05×10^5	4×10^5
South			
Min.	3×10^3	2.1×10^5	$1. \times 10^5$
Max.	93×10^3	7.9×10^5	7.95×10^5

Table II. Frequency percent of isolates from dilution plates by layer and study center.

Frequency %

Code number	Fungus	Soil North	Soil South	Roots North	Roots South	Litter North	Litter South
1.	Trichoderma sp.	50.00	56.25				
33.	Hormodendron viride	56.25	50.00				
29.		31.25	50.00				
18.	Penicillium sp.	31.25	31.25				
9.		31.25	25.00				
39.		37.50	12.50				
40.	Absidia butleri	25.00	18.75				
41.		18.75	25.00				
7.		12.50	25.00				
8.		18.75	12.50				
20.		18.75	12.50				
22.	Yeast	25.00	6.25				
47.		12.50	18.75				
62.		18.75	12.50				
12.		12.50	12.50				
15.		18.75	6.25				
16.	Trichoderma sp.	6.25	18.75				
21.	Penicillium sp.	18.75	6.25				
46.		12.50	12.50				
2.		12.50	6.25				
4.		12.50	6.25				
23.		---	18.75				
25.		12.50	6.25				
28.		---	18.75				
30.		6.25	12.50				
36.		12.50	6.25				
56.	Penicillium sp.	12.50	6.25				
10.		---	12.50				
32.		---	12.50				
42.	Penicillium sp.	6.25	6.25				
69.		6.25	6.25				
34.		---	6.25				
50.		6.25	---				
52.		6.25	---				
53.	Aspergillus niger	6.25	---				
59.		6.25	---				
60.		6.25	---				
61.		6.25	---				
67.		---	6.25				
68.		---	6.25				
70.		6.25	---				
71.		---	6.25				

Code number		Soil		Roots		Litter	
		North	South	North	South	North	South
73.		---	6.25				
74.		---	6.25				
76.		6.25	---				
6.	Penicillium multicolor	68.75	62.50	50.00	50.00	37.50	12.50
13.	Aspergillus japonicus	43.75	18.75	6.25	---	---	12.50
113.	Penicillium sp.			43.75	37.50		
116.				31.25	50.00		
126.				37.50	25.00		
127.				31.25	31.25		
136.				18.75	37.50		
128.				25.00	25.00		
133.				31.25	18.75		
112.				25.00	12.50		
114.	Penicillium sp.			6.25	18.75		
115.				18.75	6.25		
120.				6.25	18.75		
129.				25.00	---		
132.				12.50	12.50		
138.				6.25	18.75		
141.				---	25.00		
143.				6.25	18.75		
117.				6.25	12.50		
118.				12.50	6.25		
121.				12.50	6.25		
130.				12.50	6.25		
135.				18.75	---		
140.				---	18.75		
111.	Penicillium sp.			6.25	6.25		
124.				6.25	6.25		
119.				6.25	---		
125.				6.25	---		
134.				6.25	---		
137.				---	6.25		
122.				---	6.25		
139.				---	6.25		
142.				---	6.25		
144.				6.25	---		
145.				6.25	---		
146.				6.25	---		
147.				---	6.25		
148.	Yeast			6.25	---		
149.				6.25	---		
150.				6.25	---		
151.				---	6.25		
152.				---	6.25		
5.	Trichoderma sp.	93.75	87.50	93.75	93.75	25.00	37.50
19.		6.25	6.25	18.75	6.25	---	6.25
51.		18.75	---	18.75	---	---	---
78.		6.25	---	6.25	---	---	---

		Soil		Roots		Litter	
		North	South	North	South	North	South
44.	Penicillium sp.	---	6.25	6.25	---	---	---
48.						27.50	43.75
37.						43.75	25.00
49.						31.25	31.25
80.						37.50	25.00
54.						37.50	12.50
57.						31.25	12.50
84.						31.25	6.25
85.						12.50	25.00
79.						18.75	12.50
31.						18.75	6.25
43.						6.25	18.75
63.						25.00	---
81.						---	18.75
93.						12.50	12.50
98.	Penicillium sp.					12.50	12.50
102.						12.50	12.50
106.						18.75	6.25
83.						6.24	12.50
91.						12.50	6.25
96.						12.50	6.25
97.						12.50	6.25
17.						6.25	6.25
55.						12.50	---
75.						12.50	---
86.						6.25	6.25
90.						6.25	6.25
94.						---	12.50
95.						---	12.50
99.						---	12.50
101.						6.25	6.25
105.						12.50	---
107.						12.50	---
58.						---	6.25
66.	Yeast					---	6.25
82.						6.25	---
87.						---	6.25
89.						---	6.25
92.						---	6.25
100.						---	6.25
103.	Penicillium sp.					6.25	---
110.						---	6.25
11.		---	12.50	6.25	12.50	87.50	75.00
35.	Penicillium sp.	12.50	6.25	---	---	68.75	56.25
26.		---	6.25	---	---	62.50	31.25
64.		6.25	---	---	---	43.75	50.00
24.	Penicillium sp.	12.50	6.25	12.50	---	31.25	18.75

	Soil		Roots		Litter	
	North	South	North	South	North	South
3.	---	6.25	---	---	18.75	12.50
14.	12.50	18.75	---	---	18.75	12.50
77.	6.25	---	---	---	18.75	12.50
38.	6.25	---	---	---	6.25	12.50
45.	---	6.25	---	---	---	6.25

Table III. Matrix showing the index of similarity (2w/A-B x 100) for each set of samples.

		Soil		Roots		Litter	
		North	South	North	South	North	South
Soil	North	---					
	South	73.5	---				
Roots	North	25.5	18.0	---			
	South	20.6	22.5	69.6	---		
Litter	North	13.0	14.0	10.2	9.4	---	
	South	15.3	16.8	11.7	9.9	70.6	---

Table IV. Species distribution among the alcohol treated samples.

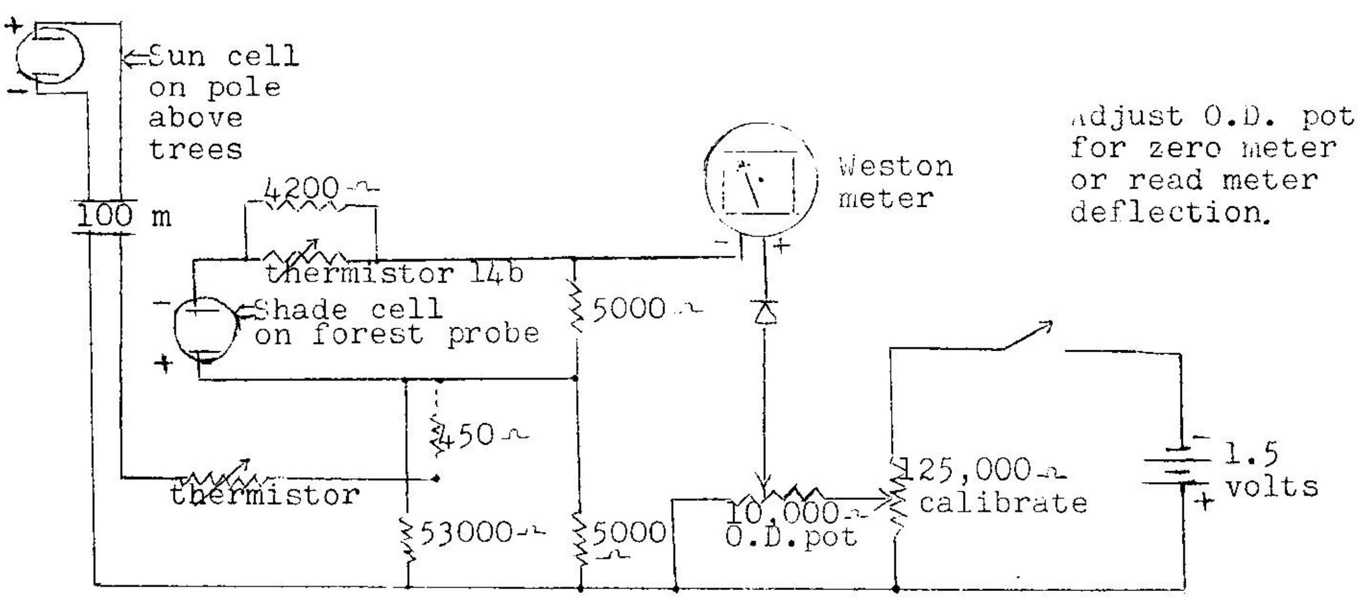
	Number of Species
Species isolated from soil only	10
" " " roots only	10
" " " litter only	10
" " " soil and roots	7
" " " soil and litter	0
" " " roots and litter	15
" " " all three layers	6
Total	58

Table V. Matrix showing the index of similarity for each set of samples.

		Soil		Roots		Litter	
		North	South	North	South	North	South
Soil	North	---					
	South	56.7	---				
Roots	North	21.3	27.1	---			
	South	18.7	29.3	52.7	---		
Litter	North	13.0	16.2	38.4	46.4	---	
	South	3.2	8.3	28.2	36.7	55.9	

Circuit of Optical Density Device

The circuit of the portable optical density device which was developed by the project in collaboration with Tropical Terrain Research Detachment of the Waterways Experiment Station (San Juan) is drawn below. This device has now been used in various systems throughout Puerto Rico. For the theoretical discussion see the 1964 report, the paper by H.T. Odum in 1963 (Natl. Acad. Sci. 49:429-434), and M. Monsi and T. Saeki in 1953 (Japan J. Bot., 14:22). The portable device in its final form involved contributions of George Drewry, William Helmut, W. Rushing, Robert Benn, and H. T. Odum.



G. Drewry

MICROBIAL DENSITY AND ACTIVITY OF THE LOWER CENTER

December 15, 1964

Martin Witkamp
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Microbial population density and activity were characterized for the top 2.5 cm of litter and soil at 10,20,30,45,60,80,100, and 150 m from the source. The transect runs from E_{10} to ESE_{100} uphill in line of sight of the source. A topographically shielded control was located in the same direction at 150 m from the source. At each distance from the source two samples were taken, one in plain sight of the source, another close by behind a large rock providing at least 25 cm of shielding and over 90% attenuation. The transect enables characterization of 1) pre-irradiation levels and variability at various distances from the source 2) trends along the transect which will have to be corrected for in order to evaluate radiation effects and 3) radiation effects at various distances. The paired samples enable additional evaluation of direct radiation effects on the microflora without secondary effects from changes in vegetation and fauna.

Paired measurements at each sampling distance were made of organic matter, and moisture content, pH, fungal and bacterial densities, and O_2 consumption. In addition CO_2 production was measured titrimetrically by using dishes with 5 ml 0.1 KOH under inverted metal boxes (15 cm diam, 30 cm high) on the forest floor at each sampling site. Paired measurements were made on 10 ml soil cores (23 mm diam., 25 mm deep) using stationary Warburg technique at 30°C for O_2 consumption, and 1 g of wet soil dilution plates with pepton-dextrose agar and nutrient agar for fungi and bacteria respectively.

To evaluate radiation effects on microbiota below 2.5 cm the same measurements as on the paired samples were made on cores from 2.5 to 5.0 cm depth taken between 10 and 30 m from the source. Effects on microbes, shielded by 2.5 cm of soil are not expected beyond 30 m from the source.

Increase in litter production during radiation and possible reduction of microbial activity may lead to litter accumulation. This situation may resemble decomposition in the mountain forest with considerable humus formation. To enable a comparison between the two cases of litter accumulation in respect to microflora and microbial activity, measurements as before were made on four soil cores from mossy cloud-forest from the top of El Toro.

Results (Table 1) show for the <u>transect series</u> that 1) there is no significant difference between the projected exposed (1-8) and shielded (S_1-S_8) series ($P > 60\%$). 2) There are no significant linear regressions for the measured variables along the transect with the exception of organic matter ($P < 5\%$), moisture ($P < 1\%$) and CO_2 evolution ($P < 1\%$), all of which increase going uphill away from the source.

ENVIRONMENTAL AND MICROBIAL DATA FROM PAIRS OF 10 ml SOIL CORES TAKEN DEC. 15 AT 8 DISTANCES EAST FROM Cs SOURCE, AND ON TOF OF EL TORO (1075m).

Origin and Sample Number	Distance from Source (m)	% Organic Matter	% Moisture	Fungi/ml	Fungi/g org.	Bacteria/ml	Bacteria/g org.	CO_2 in field ml/m^2·hr	O_2 in Warburg µl/ml·hr	pH
Transect Series 0-2.5 cm										
1	10	35	108	31	289	68	633	17.8	30	4.9
S_1	10	21	67	16	86	247	1356		24	5.1
2	20	23	98	22	153	100	686	15.2	38	5.7
S_2	20	27	101	15	110	49	360		44	5.4
3	30	23	83	21	208	29	288	17.8	22	5.1
S_3	30	20	77	10	80	35	286		30	5.3
4	45	81	194	34	187	737	4103	25.4	67	4.7
S_4	45	28	111	15	136	37	341		27	5.7
5	60	48	166	9	67	13	95	25.4	34	5.4
S_5	60	27	83	17	130	32	253		35	5.0
6	80	36	124	68	409	114	692	20.3	40	4.7
S_6	80	42	133	10	66	17	110		22	4.1
7	100	47	110	24	196	6	53	25.4	15	5.3
S_7	100	73	189	11	55	23	115		30	4.7
8	140	55	177	16	106	33	221	22.9	32	5.3
S_8	140	92	328	16	130	44	349		39	5.7
Subsoil 2.5-5 cm										
11	--	17	80	15	104	19	135	--	11	5.0
12	--	16	76	1	11	4	33	--	18	5.0
13	--	49	113	4	22	9	52	--	13	4.9
Mountain Soil										
21	--	92	416	9	62	5	34	--	20	4.5
22	--	94	463	4	24	3	18	--	30	5.4
23	--	90	453	5	37	8	56	--	29	5.4
24	--	92	450	12	90	169	1329	--	30	5.85

The subsoil (25-5 cm) consumed significantly less O_2 ($P < 1\%$) than the top layer (0-2.5 cm) of the transect series. Subsoil also contained significantly less humus and moisture ($P < 1\%$) and consumed less O_2 ($P < 2\%$) than mountain soil (0-2.5 cm).

Mountain soil contained significantly more humus and moisture and less bacteria ($P < 1\%$) than surface soil from the transect.

This caracterization of the pre-irradiation status of the microflora will be the basis for evaluation of direct and indirect effects of radiation immediately at the end of the three months irradiation period.

Aerial Monitoring of Gamma Forest

By Philip L. Johnson
USA - CREEL - Hanover, N. H.

Bimonthly photographic missions have been conducted for one year prior to treatment and will continue during the post-radiation year. Aerial and ground photographs were obtained with Kodax Plus X, Infrared, Ektachrome and Ektachrome Infrared Aero (C-D) films from a helicopter and from 11 permanent pipes within the gamma field. Results during the pre-treatment year confirm the non-seasonal nature of the forest and will be analyzed for phenological information of specific individuals. Results in the post-treatment year will demonstrate the vegetation response to treatment as opposed to normal phenological events. A series of hemispherical photographs of the forest canopy has permitted direct assessment of vegetation cover over the 11 sample points for comparison with changes due to treatment.

The aerial photography will be analyzed using a microdensitometer to associate changes in the photographic pattern with the gamma gradient introduced. It may also be possible to correlate film densities with various species or phenological events.

See Fig. 1 on page 87B.

Fig. 1 is a hemispherical photograph of the forest canopy at station 3, February 7, 1965 (1068, speed 10). See the 1964 report for a map of station positions.

Radiation Genetics and Radiation Botany

By
F. K. S. Koo and Edith Robles de Irizarry

A. Nuclear volume and radiosensitivity

Radiosensitivity is a measure of the degree of biological response to radiation. The end points employed in the sensitivity assaying can be either the lethality, growth inhibition, sterility, mutation, chromosomal aberration, physiological or biochemical changes. Often, the cause of lethality, growth inhibition, or sterility in plants is mainly genetic in nature. If the observed end point can be traced to its genetic origin, the site of the primary radiation damage must lie in the nucleus and then certain nuclear characteristics may be related to the radiosensitivity. It has been demonstrated that the nuclear volume, particularly the nuclear volume per chromosome at interphase, strongly correlates with the radiosensitivity in plant species. If the growth inhibition or lethality is used to measure the radiosensitivity, it would be most logical to study the nuclear parameters in the meristems of the shoot apices because these end points simply reflect the radiation damages in the meristems.

In the area at El Verde, a great number of plant species including trees, vines, ferns, mosses, etc. are known. Within a radius of 30 meters in both experimental sites, some 65 species, mainly trees, were tagged for study. The abundance of the material provides an unusual opportunity for studying the relationship between nuclear volume and radiosensitivity.

To prepare the meristems for nuclear volume measurement, the terminal shoot apices were collected and fixed in Craf III. The material, after being washed thoroguhly, was processed through a dehydration - infiltration schedule using ethyl and tertiary butyl alcohols, embedded in paraffin, sectioned at the thickness of 10 - 12 u, stained with safranin, crystal violet, and orange G, and mounted. The nuclei of the cells in the tunica and outer corpus were measured with an ocular micrometer at a magnification of 800 x. For each nucleus two measurements in diameter at right angles to each other were taken. For each species, in general two meristems with 10 nuclei in each were measured and the average nuclear volume was calculated from the measurements of individual nuclei assuming a spherical shape of the nucleus.

Presented in Table 1 are the nuclear volume measurements for 66 plant species. *Miconia tetrandra* has the smallest nuclear volume which measured 23.6 u^3 and *Smilax coriacea* the largest, 335.6 u^3. The two extremes represent a 14-fold difference in nuclear size. In the Table there are 33 species with a nuclear volume less than 100 u^3, 25 species in the range of 100-200 u^3, 6 species in the range of 200 -300 u^3, and only 2 species over 300u^3. Based on the known fact that pitch pine and other species have large nuclear volumes and high radiosensitivity,

Table 1.

Nuclear volume measurements (in u^3) of shoot apices of plant species grown at the radioecology experimental sites at El Verde.

Species	Nuclear volume ± SE (u^3)
Miconia tetrandra	23.6 ± 6.6
Tilladsia curvata	27.3 ± 9.4
Elsota virgata	31.4 ± 8.3
Matayba domingensis	33.7 ± 8.2
Sloanea berteriana	34.0 ± 4.2
Comocladia glabra	34.8 ± 13.0
Ficus laevigata	35.9 ± 7.8
Casearia bicolor	38.0 ± 13.5
Ormosia krugii	40.5 ± 13.6
Casearia sylvestris	41.3 ± 13.7
Allophylus occidentalis	41.6 ± 13.0
Rourea glabra	41.7 ± 11.0
Neorudolphia volubilis	47.4 ± 14.0
Dacryodes excelsa	52.6 ± 16.9
Casearia arborea	58.2 ± 19.6
Cordia sulcata	62.3 ± 15.9
Tetragastris balsamifera	62.5 ± 12.5
Casearia guianensis	64.0 ± 9.3
*Cassiapourea alba	64.8 ± 11.6
Guzmania lingulata	67.7 ± 18.0
*Ocotea portoricensis	68.8 ± 13.3
*Rheedia acuminata	69.4 ± 15.8
+Homalium racemosum	69.4 ± 12.3
Guettarda laevis	69.7 ± 9.3
Tabebuia heterophylla	73.3 ± 18.1
+Cyrilla racemiflora	75.8 ± 9.8
Mangifera indica	77.4 ± 13.2
Inga laurina	79.7 ± 15.4
Cecropia peltata	80.3 ± 12.9
*Eugenia stahlii	81.6 ± 17.2
Ixora ferrea	91.6 ± 13.6
*Miconia prasina	93.6 ± 18.9
Piper treleaseanum	94.9 ± 21.9
+Miconia sintensii	100.0 ± 24.2
*Micropholis garcinaefolia	100.3 ± 20.7
+Ocotea leucoxylon	101.8 ± 25.1
Drypetes glauca	101.9 ± 19.5
Guarea guara	102.0 ± 20.6
Paullinia pinnata	102.2 ± 13.8
Euterpe globosa	103.7 ± 27.1
Banisteria laurifolia	112.4 ± 26.0
Exogonium repandum	113.4 ± 21.6
Didymopanax morototoni	116.1 ± 27.6

Note: These names are based on the old table and have not yet been converted to names given on page 54. Some of these grow at the El Verde station but not actually in the radiation center.

Species	Nuclear volume ± SE (u3)
Alchorneopsis portorricensis	118.7 ± 26.3
Byrsonima spicata	122.4 ± 26.9
Psychotria berteriana	130.9 ± 24.8
Phylodendron lingulatum	143.2 ± 33.4
Roystonea berteriana	145.6 ± 19.0
Phylodendron krebsii	146.3 ± 27.0
Cananga caribaea	147.1 ± 10.4
Daphnopsis philippiana	148.9 ± 42.6
Anthurium dominicensi	156.3 ± 16.8
Ocotea moschata	158.7 ± 31.4
Skelegelia portorricensis	161.5 ± 37.3
+Buchenavia capitata	164.1 ± 38.4
Palicourea riparia	176.5 ± 34.1
Manilkara nitida	179.3 ± 37.6
Rajania cordata	189.2 ± 54.7
Alchornea latifolia	219.2 ± 88.8
Drypteris deltoidea	227.7 ± 43.9
Meliosma herbertii	231.6 ± 41.4
Marcgravia rectiflora	232.3 ± 85.4
*Cordia boringensis	252.8 ± 26.2
Croton poecilanthus	260.0 ± 59.4
Magnolia splendens	314.0 ± 42.3
Smilax coriacea	335.6 ± 57.0

*With only 1 meristem studied
+Measurement for dormant meristems

most of these tropical species may be considered relatively tolerant to radiation and some of them highly radioresistant.

The nuclear volume of a species often varies with the season. More precisely, it varies with the state of the meristem. In this study, a number of species have been measured for both the actively growing and non-active or slow-growing meristems (Table 2). The differences in all cases are very pronounced. The percent increases of the actively growing shoot apices over the inactive or slow-growing ones are from 27% for Cordia boringuensis to 157% for Euterpe globosa.

It is of both theoretical and practical interest to make predictions on the radiosensitivity of the species based on the nuclear volume measurements. However, it should be pointed out that the predictions can be regarded only as approximations and they represent only the general range of the sensitivity of the species with that nuclear volume. In this study, the total dose levels that could cause over 90% mortality, 20% and 80% shoot growth reductions (Table 3) are predicted by considering the predicted and actual doses for the same effects presented by Woodwell and Sparrow for the species in the oak-pine forest at Brookhaven. The total dose level for lethality is therefore calculated on the basis of 1-year exposure and that for shoot growth reduction on a 9-month exposure basis. Since our total irradiation period is scheduled for 3 months only, the results may differ somewhat from that observed under much longer period of radiation exposure. In

Table 2.

Percentage of increase in nuclear volume measurements of actively growing shoot apices over inactive or slow-growing ones.

Species	Nuclear volume ± SE (u^3) Actively growing shoot apices (A)	Inactive shoot apices (B)	% increase (A over B)
Cassiapourea alba	64.8 ± 11.6	41.5 ± 12.5	56
Eugenia stahlii	81.6 ± 17.2	55.2 ± 9.9	48
Miconia prasina	93.6 ± 18.9	69.9 ± 11.8	34
Euterpe globosa	103.7 ± 27.2	40.4 ± 11.5	157
Palicourea riparia	176.5 ± 34.1	100.9 ± 28.0	75
Manilkara bidentata	179.3 ± 37.6	87.1 ± 26.8	106
Cordia borinquensis	252.8 ± 26.2	199.5 ± 77.6	27

Table 3.

Predicted total dose levels for 90% mortality, 80% and 20% shoot growth reductions in tree species with various nuclear volumes grown at Cs-137 gamma irradiation site at El Verde.

Nuclear volume (u^3)	90% Mortality dose (Kr)	80% growth reduction dose (Kr)	20% growth reduction dose (Kr)
20	198.0	28.22	4.46
30	137.0	19.52	3.08
40	105.0	14.96	2.36
50	86.0	12.26	1.94
60	73.0	10.40	1.64
70	64.0	9.12	1.44
80	56.5	8.06	1.28
90	50.7	7.22	1.14
100	46.0	6.56	1.04
110	42.0	5.99	.95
120	39.0	5.56	.88
130	36.2	5.16	.81
140	34.0	4.85	.77
150	32.0	4.56	.72
160	30.0	4.28	.68
170	28.4	4.05	.64

Nuclear volume (u^3)	90% Mortality dose (Kr)	80% growth reduction dose (Kr)	20% growth reduction dose (Kr)
180	27.0	3.85	.61
190	25.8	3.68	.58
200	24.6	3.50	.56
210	23.5	3.35	.53
220	22.5	3.21	.51
230	21.6	3.08	.49
240	20.8	2.96	.47
250	20.0	2.85	.45
260	19.3	2.75	.44
270	18.6	2.65	.42
280	18.0	2.57	.41
290	17.5	2.50	.39
300	17.0	2.42	.38
310	16.5	2.36	.37
320	16.0	2.28	.36
330	15.6	2.22	.35
340	15.2	2.17	.35

addition, other factors such as biological and inanimated shieldings could also contribute many discrepancies to the predictions. Above all, the standard errors for the nuclear volume measurements are relatively high, so the predicted dose for each of the effects may very well vary within ±20% even though other factors are not considered.

A count of plants in each species killed by radiation will be made soon after a 3-month exposure and at intervals thereafter for a period of about one year. Because the number of species is large only a few species can be found within a small area close to the radiation source where the total accumulative dose is high enough to produce the killing effect. For the species which have some killing and also are abundant in the area, their response to radiation may be studied at all dose levels. But for others, only the low-dose effects may be assessed.

For the growth inhibition measurements, two studies, one on shoot growth reduction and the other on trunk circumference growth reduction, have been initiated by other investigators of the Program. Their results certainly can be correlated with the nuclear volume measurements to check out the validity of the prediction.

However, the most critical information on the radiosensitivity of these species must come from irradiation experiments performed under controlled conditions. In this type of study, acute gamma irradiation can be used to study the survival and growth reduction of seedlings in the green house. Seeds of several tree species have been studied for their germinability and the most serious problem so far encoutered has been the poor and uneven germination. Improvement in methods of germination may be found after further testing, at least for some of the species. So the radiosensitivity for a selected group of species can be studied.

B. Moss Investigation

Dr. W. C. Steere of the New York Botanical Garden collected and identified 20 species of mosses in the rainforest at El Verde. Preliminary results on the nuclear volume measurements for all 20 species have been obtained*. The range varies from approximately 4 u^3 to 140 u^3, indicating a 35-fold difference in volume between the two extremes. A number of species show that the nuclear volume taken from the base cells of the top "leaf" is quite different from that of the lower "leaf". In some instances, a 10-fold difference in volume is observed. In general the cells from the top "leaf" have larger nuclear volume, but this is by no means the rule. For a few species the apical points have also been studied for the nuclear volume. The measurements appear to be comparable to the ones on the top "leaf" of the species. The nuclear volume study has been done with the aceto-carmine squash method.

Attempts have been made to culture and propagate the moss species in the growth chamber. Eight out of 20 species have survived and begun to show new growth. This survey would help to determine the feasibility of radiosensitivity study with mosses under controlled conditions.

(*This investigation has been assisted by Robert Venator)

C. Bromeliad Investigation

Two species of Bromeliad collected at El Verde were irradiated with gamma rays at doses of 0, 3, 6, 12, 24, 48, 96, and 192 kr. Ten plants from each treatement for each species were planted in the shaded greenhouse with ample mist spray. At the end of one month following irradiation, all plants of both species that received 192 kr died. The plants at intermediate dose levels showed some browning and spotting. There was no apparent sign of any radiation damage at low doses. At the end of 2 months, 5 and 3 plants of the broad-leaf and narrow-leaf species, respectively died in the 96 kr series and one plant of broad-leaf species died in the 48 kr series. At the end of 3 months all the plants of both species in the 96 kr series, and one plant each from the two species in the 48 kr series died. In the broad-leaf species, one and two plants in 12 kr and 6 kr series, respectively, also died. It is apparent both species are tolerant to radiation although the broad-leaf species is less so.

Another set of experiments with the same two species has been under way at the irradiation site at El Verde. The plants were grown on the plates cut out from tree fern trunks for a period of one month in the shaded greenhouse under constant mist spray and then moved to the rainforest before the beginning of irradiation. The plates were hanged on the tree trunks about 6-8 feet from the ground at a distance interval of approximately every 5 meters up to 50 meters from the Cs-137 gamma source. At each location randomly placed was a set of 4 plates consisting two replications with 10 plants in each replication for each species. Two sets of controls were also placed at two locations some distance from the radiation source. All the sets were tagged with dosimeters. Data on survival and growth of new leaves have been collected on two occassions.* Further information will be gathered following a 3 month exposure period.

(* This study has been assisted by Robert Venator)

D. Other Studies Planned

The Cytogenetic effects of chronic gamma irradiation on tree species are of special interest to us. Plans have been drawn up to study the chromosomal aberrations in the microsporocytes and sterility in the pollens of a selected group of species.

Also a limited number of tree species will be studied for the radiation damage to the meristems.

The material for these studies will be collected at various distances from the source, preferably at locations where the dose levels are known.

Gamma radiation effect on chlorophyll A content in Bromeliads.

F. K. S. Koo, H. T. Odum,
Edith Robles de Irizarry and Marta De Arce

Under the same environmental conditions the ratio of photosynthetic rate of a plant to its chlorophyll content holds constant and any change in the amount of chlorophyll in the plant is reflected in the change in its photosynthesis. So an estimate of the photosynthetic rate may be made by measuring the amount of chlorophyll. Ionizing radiation is known to affect chlorophyll biosynthesis. In this study, chlorphyll content was assayed to serve as an indirect measure of radiation interference with the photosynthetic mechanism in the irradiated plants.

The broad-leaf Bromeliad plants,12 in each group, were treated with gamma-rays at dose levels of 0, 2.5, 5, 7.5, 10, 25, 50, 75, 100, 150 and 200 kr and planted in the shaded greenhouse with about 8 hrs. of mist spray a day. For chlorophyll "A" determination, at each collection date 4 leaf samples, one from each plant, were collected from the control and each of the 10 irradiated series. A single disk in the size of 1 cm^2 was then taken from each leaf using a cork hole puncher. Leaf disks were extracted individually in 90% acetone, optical density was measured, and chlorophyll A was computed according to absorbencies given by Richards and Thompson. An abbreviated procedure was used involving the determination of optical density at 665 millimicrons only using the relatively broad band pass of the Bausch and Lomb spectrophotometric colorimeter. Readings in this instrument were calibrated using the same solutions in a Beckman narrow band pass spectrophotometer according to Richards and Thompson's procedures.

Seven collections were made over a period of 2 months, beginning on the day of irradiation and thereafter about every 10 days. Only the young leaves were taken, and all plants were about equally sampled in the whole period of study. Starting with the second date of collection, leaves sampled were first read on a transmission densitometer "Welch Densichron" for ASA diffuse transmission densities before leaf disks were taken.

Presented in Table 1 are mean chlorophyll A content (g/m^2) in young leaves of the control and gamma irradiated series. The samples collected on the first date in general yielded about 0.2 g/m^2 or more except that in the 200 kr series. Samples collected 11 days later showed a drastic 50% decrease in chlorophyll content but further decrease at later collections were less pronounced. With the exceptions that occurred in the first two dates of collections, in general the chlorophyll content decreased with increasing radiation dose. The increase in content at low dose levels as shown in the second collection (Oct. 26) may indicate a stimulative effect. However, the increase of content observed at dose levels of 5 - 150 kr over the control value at the first collection (Oct. 15) cannot be explained on the same basis as these samples were collected immediately following irradiation. Statistical analysis indicates that the differences are not significant. On the other hand, the

Table 1. Mean chlorophyll A content (g/m^2) in young leaves of control and gamma-irradiated bromeliad plants. Leaf samples were collected at intervals of about every 10 days Oct. 16-Dec. 15, 1964. F values from analysis of variances are included

Treatment (gamma rays in kr)	Collection date							F value
	Oct. 15	Oct. 26	Nov. 4	Nov. 13	Nov.24	Dec. 4	Dec. 15	
0	0.192	0.105	0.108	0.118	0.070	0.074	0.059	5.33**
2.5	0.178	0.109	0.096	0.122	0.081	0.078	0.059	4.50**
5	0.226	0.129	0.088	0.084	0.100	0.102	0.077	11.78**
7.5	0.242	0.133	0.081	0.092	0.099	0.091	0.036	44.21**
10	0.209	0.128	0.085	0.086	0.080	0.087	0.060	15.78**
25	0.236	0.088	0.081	0.085	0.061	0.076	0.0035	27.53**
50	0.241	0.112	0.068	0.074	0.054	0.051	0.030	43.19**
75	0.230	0.100	0.067	0.056	0.032	0.050		23.97
100	0.229	0.089	0.036	0.069	0.0048	0.014		30.68**
150	0.143	0.049	0.021	0.031	0.0098	0.029		26.33**
F value	1.53	3.76**	10.31**	0.58**	31.41**	11.00**	22.50**	

**Significant at 1% level

analyses of variances for the other 6 collections indicate in each case the variance ratio of "between treatments" to "within treatments" is highly significant. Since the data in Table 1 also show that the chlorophyll A content generally decreased as the length of time the plants growing under the shaded greenhouse conditions increased. The results from the statistical analyses indicate that in all cases the variances for "between collection dates" over that for "within collection dates" are highly significant. At each collection, difficulties in sampling the young leaves of the same age were encountered. Also on some occasions some necrotic tissues were included in the sampling as the browning effect spread over the leaves at high dose levels, especially at later collections. These factors might have contributed to some of the unexpected irregular variations in Table 1. Also it should be pointed out that at the end of one month following irradiation, all plants at the 3 highest dose levels were nearly dead or completely dead.

The mean diffuse transmission density readings for the leaves collected for chlorophyll A determination are presented in Table 2. The readings, almost following the same pattern as for the chlorophyll content variation, decreased as the doses and the days grown in the greenhouse increased. The readings of the individual leaf samples were used to correlate with the chlorophyll A content of the same sample. The results

Table 2

Mean diffuse transmission density readings (with Welch Densichron) of young leaves of control and gamma-irradiated Bromeliad plants collected for chlorophyll A determinations

Treatment gamma rays in kr)	Collection date					
	Oct. 26	Nov. 4	Nov. 13	Nov. 24	Dec. 4	Dec. 15
0	0.57	0.56	0.58	0.50	0.46	0.46
2.5	0.63	0.58	0.64	0.54	0.48	0.40
5	0.60	0.52	0.63	0.61	0.51	0.51
7.5	0.61	0.53	0.58	0.58	0.52	0.40
10	0.59	0.51	0.58	0.57	0.51	0.46
25	0.56	0.53	0.55	0.48	0.50	0.38
50	0.56	0.52	0.54	0.44	0.36	0.40
75	0.59	0.51	0.47	0.38	0.45	
100	0.54	0.47	0.53	0.36	0.36	
150	0.52	0.45	0.31	0.36	0.38	
200	0.45	0.39	0.32	0.34	0.43	

of the correlation study for the samples collected at each date are presented in Table 3 and the r values in all cases are highly significant. Therefore, the diffuse transmission density determination may be substituted for the chlorophyll A determination which appears to be much more tedious than the Densichron reading.

In conclusion it may be stressed that in general gamma radiation at a dose level of 50kr or higher produces a profound damaging effect on chlorophyll biosynthesis in Bromeliad plants, and that no recovery from radiation damage was observed at these high dose levels. However, the plants that received lower doses tended to recover at later date.

Table 3

Correlation between chlorphyll A content and diffuse transmission density reading of individual leaf samples of control and gamma-irradiated Bromeliad plants collected at 6 dates.

Collection date	No. pairs of values	r
Oct. 26	44	0.85**
Nov. 4	44	0.81**
Nov. 13	44	0.84**
Nov. 24	44	0.86**
Dec. 4	44	0.70**
Dec. 15	28	0.50**

**significant at 1% level.

Note: The thin leaved bromeliads are very young individuals which later develop broader leaves. The population in these experiments was a mixture of Guzmania and Trichomanes.

Chromosome relations in the Insect Populations of El Verde.

Niilo Virkki
Cytogeneticist
Agricultural Experiment Station
Río Piedras, P. R.

Since the last report, work could be continued with Phasmids only. 150 permanent slides were made from 4-5 species occurring in the irradiation area. The material will be studied in detail after the identification of the specimens has been arranged.

In most specimens, 14+X (male) or 14+XX (female) is the meiotic chromosome number. In one single specimen was a naturally occurred chromosomal rearrangement detected. The specimen was heterozygous in relation with an autosomal centric fusion, the number being: 15 bivalents + 1 trivalent + X.

Frog Noise Progress Report

By George Drewry

The record of frog noise now includes a complete annual cycle. It is interesting to note that the winter of 1964-65 has had the same effect or the overall activity pattern as the winter of 1963-64, although the 63-64 winter was much drier. In addition to the equipment described a second frequency has been added to the one used in the study of *Eleutherodactylus portoricensis*. The second frequency was chosen to be the dominent sound of two species, *E. hedriki* and *E. eneidae*. The occurrence of considerable sound from *E. portoricensis* at this frequency requires detailed analysis of the record to separate the other two species. Preliminary analysis combined with field notes suggests that these species use time separation to avoid interference under normal circumstances. A definite decline in the activity of *E. hedriki* precedes the development of the peak sound intensity of *E. eneidae*, whose principle activity occurs after midnight. A detailed analysis of call structure in these and several other species is now under way, with plans for development of a multi-channel recording instrument plotting each species separately.

Cytological Study of Ferns and Fern Allies in El Verde

by Veikko Sorsa
Associate Cytogeneticist
Institute of Genetics, University of Helsinki, Finland

Eighteen different species of ferns and fern allies were registered in the Project Areas by me and my wife Mrs. Marja Sorsa in August 1964. Material for cytological studies was fixed from all species found in the meiotic stage. In case the chromosome number could not be counted from material fixed from the Project Areas, it was determined from material of the same species collected around the Project Areas in El Verde.

Microscope preparations were made and the investigation was carried out in the Institute of Genetics, University of Helsinki, Finland. Camera lucida drawings have been made of the chromosomes of the species studied. Photomicrographs have been taken of the cytologically most interesting species.

The herbarium specimens of the collected material were kindly named by Dr. R. Woodbury in the Agricultural Experiment Station, Rio Piedras.

Observations

Center:

Distance from the center	Name of species	Chromosome number counted: From Project Area	From outside
3.2m or less	Adiantum cristatum L.	chromosomes not countable	
	Alsophila borinqueña Maxon	n = 69 - 70	n = 69
	Dryopteris deltoidea (Sw.)Kuntze	n = 41	n = 41
3.2 - 10 m	Polypodium chroodes Spreng.	chromosomes not countable	
"	Dryopteris deltoidea (Sw.)Kuntze	n = 41	n = 41
"	Alsophila borinqueña Maxon	---	n = 69
"	Elaphoglossum flaccidum (Fée)Moore	n = 41	n = 41
10 - 30 m	Alsophila borinqueña Maxon	n = 69	n = 69
	Dryopteris deltoidea (Sw.) Kuntze	n = 41	n = 41
	Adiantum cristatum L.	---	---
	Elaphoglossum flaccidum (Fée)Moore	n = 41	n = 41
	Nephrolepis rivularis (Wahl)Mett.	chromosomes not countable	
	Oleandra articulata (Sw.) Presl.	n = 41	n = 41
	Asplenium cuneatum Lam.	n = 72	n = 72
	Polypodium chnoones Spring	---	---

	Hemitelia horrida (L.) R. Br., Spreng.	n = 70	n = 69-70
	Trichomanes capillaceum L.	chromosomes not countable	
	Lindsaea montana Fée	chromosomes not countable	
	Elaphoglossum firmum (Mett.) Urban	n = 41	n = 41
30 - 80 m	Alsophila borinqueña Maxon	n = 69	n = 69
	Polypodium lycopodioides L.	chromosomes not countable	
	Hemitelia horrida (L.) R. Brs., Spreng.	n = 70	n = 69-70
	Hypolepis repens (L.) Presl.	n = 39	n = 39
	Blechnum occidentale L.	n = 64	n = 64
	Lycopodium linifolium L.	n = c. 140	---
	Lycopodium dichotomum Jacq.	n = 132-137	---

South Control Center

Distance from the center	Name of species	Chromosome number counted From Project Area	From outside
3.2 m or less	Alsophila borinqueña Maxon	---	n = 69
	Dryopteris deltoidea (Sw.) Kuntze	---	n = 41
	Nephrolepis rivularis (Wahl) Mett.	---	---
3.2 - 10 m	Alsophila borinqueña Maxon	n = 69	n = 69
"	Dryopteris deltoidea (Sw.) Kuntze	n = 41	n = 41
"	Oleandra articulata (Sw.) Presl.	---	n = 41
"	Polytaenium feei Maxon	---	n = 60
"	Asplenium cuneatum Lam.	n = 72	n = 72
"	Danaea nodosa (L.) Smith	chromosomes not countable	
"	Lindsaea montana Fée	chromosomes not countable	
10 - 30 m	Dryopteris deltoidea (Sw.) Kuntze	n = 41	n = 41
"	Elaphoglossum firmum (Mett.) Urban	n = 41	---
"	Elaphoglossum flaccidum (Fée) Moore	n = 41	n = 41
30 - 80 m	Alsophila borinqueña Maxon	n = 69	n = 69
"	Blechnum occidentale L.	n = 64	n = 64
"	Dryopteris deltoidea (Sw.) Kuntze	---	n = 41

Species collected closely outside the circle of 80 m.

Spore and gametophytes of these species may possibly be found from inside of 80 m's circle on the Project Area as well.

80 - 300 m	Nephrolepis biserrata (Sw.) Schott	n = 41
	Dryopteris reticulata (L.) Urban	n = 72
	Polypodium astrolepis Liebm.	n = 74
	Polypodium pectinatum L.	n = 37
	Polypodium piloselloides L.	n = 74
	Asplenium abscissum Willd.	n = 144
	Asplenium salicifolium L.	n = 72
	Dryopteris decussata (L.) Urban	n = 72
	Dryopteris chaerophylloides (Poir.) C. Chr.	n = 41
	Dennstaedtia ordinata (Kaulf.) Moore	n = 41
	Polypodium taxifolium L.	n = 37
	Polypodium aureum L.	n = 74

Most of the fern species collected from the Project Areas have not been cytologically studied before. Only three are previously reported in cytological literature: Olendra articulata 2n = c. 144 by de Litardiere 1920, Cellule 31: 255-473; Asplenium cuneatum n= c.72 and n= c.216 by Manton 1959, Alston 1959: 75-81; and Blenchnum occidentale 2n= c. 124 by Abraham et al., J. Ind. Bot. Soc. 41: 339-421.

The chromosome number n=72 found in some species of Dryopteris (D. decussata and D. reticulata) is interesting, because it is quite different from the numbers n= 41 and n= 82 previously counted in the fern genus Dryopteris.

More detailed reports on chromosome conditions in Puerto Rican ferns will be published later by the author.

Summary of Pre-irradiation Chlorophyll Measurements
(Odum, Marta De Arce, Murphy)

On each of the following trees, 40 leaves were analyzed for chlorophyll, 10 new sun leaves, 10 new shade leaves, 10 old sun leaves, and 10 old shade leaves. Numbers are those on the tags in the field.

Species	Radiation Center	South Control Center
Dacryodes excelsa	2694 2695, 331	20,001
Manilkara bidentata	2680, 2702, 2288, 2640	A2,375
Euterpe globosa	2421, 2979, 2489	10,185
Croton poecilanthus	2506, 2582	X-56
Sloanea berteriana	806, 3120	Ma-1;
Cecropia peltata	-	20,000, X-63

Report on preliminary survey of bryophytes of El Verde
sites, before irradiation, December 11-16, 1964.

William C. Steere
N. Y. Botanical Garden

The investigator, William C. Steere, and his assistant, Dorothy O. Steere, arrived in Puerto Rico on December 10, and spent December 11 through 16 in a survey of the El Verde sites and December 17-19 in Rio Piedras, in supplementary studies.

Because mosses turned out to be among the most resistant plants in the Brookhaven experiments on the effect of Cesium irradiation on oak-pine forests on Long Island, I was pleased to be invited to participate in the pre-irradiation survey of the tropical rain-forest near El Verde, in the Luquillo Mountains of easternmost Puerto Rico. Whether it is the small nuclear volume of the moss cell or some other factor that gives mosses their unanticipated resistance to ionizing radiation is still not known; under any circumstances, it is surprising that a haploid plant should be resistant at all because of its lack of duplicate genes and a resultant reduction in genetic resources.

Activities. The upper and lower sites were visited on December 11, 12, 13, 15,and 16, and Smith's "equal area" site, below Site 1, was examined on December 14. The forest above the sites was visited several times, to gain a better understanding of the vegetation as a whole, and the transition from the somewhat reduced montane forest to the high rain forest. December 14 was spent largely in the montane forest about Mt. El Toro, southeast of the El Verde area.

Procedure. In the sites themselves, careful notes were taken on the bryophytes that were especially conspicuous within the 10-meter zones, and photographic records were made. Outside the 10-meter zone, notes and photographs were taken in different types of habitat, and in different degrees of exposure as determined by thelay of the land. Where possible, notes and photographs were tied to points that can be found again after radiation ceases, as numbered trees and numbered photographic points. Voucher collections made for permanent reference were documented in the same manner, and left in Rio Piedras.

Nuclear volumes. Plentiful lots of living mosses and few hepatics, 20 species in all, were collected for Dr. Koo, for determination of nuclear volumes. Because of the simple structure of bryophytes, whose leaves are normally only a single layer of cells thick, a relatively uncomplicated technique should suffice for this determination. If meristematic areas must be used, to conform to the practice already established for higher plants, the growing points of moss and hepatic stems are small and easily "squashed" out, thus avoiding the time-consuming and laborious techniques of embedding in paraffin and cutting serial sections.

Cytological study. Material of moss capsules at the proper stage to demonstrate meiosis, for chromosome counts of 15 species was collected. However, as it could not be examined at once, for lack of microscopic facilities

Table I. Bryophytes of site 1, site 2 and their vicinity

1. Dominant and conspicuous mosses in the site areas:

Thuidium urceolatum Lor. On stones, rocks, roots, and base of trees.

Taxithelium planum (Brid.) Mitt. On rocks, roots and trunks of fallen trees

Syrrhopodon berterianus (brid.) C.M. Common on trunks of *Euterpe* (sierra palm); on tree #10396, for example.

Syrrhopodon prolifer Schwaegr. On rotten wood and tree bases.

Octoblepharum pulvinatum (D. & M.) Mitt. On rotten wood and base of trees; rarely on rock

Leucobryum martianum (Hsch.) Hampe. On rotten wood and base of trees

Leucoloma serrulatum Brid. On tree trunks, twigs and rocks.

2. Less abundant mosses, but still easily oberved:

Neckeropsis undulata (Hedw.) Reich. On base of trees

Homalia glabella (Hedw.) Mitt. On vertical rock-face

Porotrichum fasciculatum (Hedw.) Mitt. On shaded rock; more rarely on tree trunks.

Syrrhopodon ligulatus Mont. On tree trunks; tree #10277 for example.

Rhizogomium spiniforme (Hedw.) Bruch. On moist shaded trunk of *Euterpe*.

Calymperes lonchophyllum Schwaegr. On base of trees; more rarely on rock

Leucomium compressum Mitt. On stones and clay soil

Crossomitrium orbiculatum C.M. On roots and twigs in moist shaded places; also on living leaves.

Fissidens pellucidus Hsch. On moist clay

Fissidens Garberi Sull. & Lesq. On tree trunks and rocks; on stone at base of tree #01173

3. Common hepatics, often abundant:

Plagiochila: at least 3 species occur on rocks and tree trunk at and near sites

Bazzania: at least two species on base of trees and on rocks; at base of tree #10398

Riccardia: several species on stumps, rotten wood and clay

Lophocolea: a common hepatic on rotten wood and base of trees

Calypogeia: a common hepatic on moist soil and rotten wood

Many species in many genera of Lejeuneaceae occur over the whole area, but a specialist will be needed to name them. These are the usual hepatics of fallen leaves.

at El Verde, and was studied only several days later (December 17 and 18), in the Institute of Tropical Forestry in Rio Piedras, the cytological data obtained were disappointing. Accurate chromosome counts could be made in only one species, a species of Callicostella still to be identified, (probably C. pallida). However, all the species that occur within the area of high irradiation also occur in areas beyond the reach of irradiation, or in areas protected from it. Consequently, if anomalies are found in the cytological behavior of bryophytes after irradiation, good control material can also be easily found and studied for comparison. By getting fresh material one day at El Verde and studying it the next in Rio Piedras, thus giving meiosis no chance to "run down", a more successful cytological program can be forecast for the future.

Post-irradiation phase. For the post-irradiation phase, it is proposed to compare the "after" with the "before" in terms of absolute and differential susceptibility among species of bryophytes which will be reflected by changes in normal associations of species. The mortality and survival should be studied from the standpoint of distance from the source, protection given by the habitat and other variables, especially in comparison with photographs taken in December. A comparative study of the production of sex organs and of sporophytes should be made between irradiated and non-irradiated populations of the same species. Anomalies of all types should be studied critically in an attempt to discover their point of origin. Meiosis should be investigated in populations that have been irradiated to determine whether or not meiotic behavior as well as chromosome number has been affected. Since the behavior of tropical mosses under irradiation has never been observed, it is difficult to forecast what will happen--but whatever happens will be significant.

Biomass in Lower Forest Strata.

Oven dry weight of materials from 5 quadrats at El Verde including breast high level and below. Data obtained by forest team under direction of Dr. J. D. Ovington. Nov. 22, 1963. Grams per square meter.

Quadrat	1	2	3	4	5	Average
Relatively Fresh Leaves	11.0	6.2	15.7	23.2	15.9	14.4
Relatively Fresh Branches	12.2	29.3	72.5	22.5	16.4	30.6
Decomposing Leaves	85.2	111.9	106.9	164.7	79.1	109.6
Decomposing Branches	14.6	91.7	117.6	7.7	3.6	47.0
Total of Leaf and Branch Material	123.0	239.1	312.7	218.1	115.0	201.6
Surface Roots, upper 10 cm	277.6	100.5	188.2	64.0	178.7	161.8
Total	400.6	339.6	500.9	282.1	293.7	363.4

Observations on Algae at El Verde, Oct. 1-9, 1964

By Phil Halicki

Preliminary observations were made on the distribution of epiphytic, lignophilic, and lithophilic species of algae at the El Verde site. In addition, collections of algae, mosses and liverworts comprising the cryptogamic community on leaves, wood, and rock, were also made.

Algae from leaf surfaces were collected during seven transects starting from the outer boundary of the upper center to the outer boundary of the lower center. The epiphytic algae were present on several species, but especially abundant on Euterpe globosa, Dacryodes excelsa, and Sloanea berteriana. In extremely wet and very humid parts of the sites Drypetes glauca also was a good substratum for algal species. Epiphytic algal species were lacking on all specimens of Cecropia peltata examined.

The most common algal genera on the leaf surfaces are Phycopeltis (Millardet) Printz, Cephaleuros Kunze, and Trentepohlia Mart.

The macroscopic appearance of Phycopeltis varied with the quantity of light present. Thalli growing in deep shade were green in color. With increasing exposure to light and seemingly less humid conditions the thalli were pale to bright lemon yellow, orange, orange-red or copper-red. The color is due to an increase in the carotenoid pigments and to the carotenoid pigments and to the storage of oil. At higher elevations than present at the experimental sites on El Yunque, 3496 ft., the genus became a deep orange-red. Within the study site Phycopeltis was parasitized by Ascomycete fungi and involved in a lichen association. Phycopeltis was abundant on several species, but most common throughout the study area on Euterpe globosa which is seemingly an excellent site for leafy liverworts, mosses, and algae other than Phycopeltis.

The genus Trentepohlia was second in abundance on the leaf surfaces. It is perhaps of some ecological worth to note the difference between the growth habit of Trentepohlia and other epiphytic algal genera. Trentepohlia is a green algal genus closely related by reproduction type to Phycopeltis. Trentepohlia is coarsely filamentous and the filaments occur at random over the leaf surface. The genus Phycopeltis, on the other hand, is a parenchymatous to pseudoparenchymatous thallus tightly appressed to the epidermal surface.

Since many representatives of this genus were sterile when collected, living material was sent to the home institution of the investigator for culture and eventual species determination. Much of the Trentepohlia collected was also parasitized by Ascomycete fungi.

The epiphytic algal genus least abundant was Cephaleuros. As with other Trentepohliaceous general Cephaleuros possesses an erect and prostrate system. Unlike Phycopeltis and Trentepohlia, Cephaleuros has filaments which actually penetrate the cuticle and epidermis of the host and may become an intramatrical space parasite. In seven transects throughout the site Cephaleuros was collected only twice on Sloanea berteriana.

Because of the rather common occurrence of Phycopeltis, liverworts, mosses, and other algae on the leaves of Euterpe globosa special emphasis was placed on study of this palm. A problem of interest is the relative life-span of a palm frond. Fifty representatives were selected along the trail center to the lower center as shown in the map (Fig. 1). The outermost frond of each individual was marked with a metal tag. Alejo Estrada Pinto makes monthly observations on the life of the palm fronds.

After returning to his home institution the investigator will make total counts for the relative distribution of Phycopeltis on Euterpe leaves. This will again be done after irradiation. In addition to the study of the Euterpe leaf community, 20 rocks or rock-log aggregates were marked for study of lithophilic and lignophilic species. Permanent green concrete markers of these rock-wood sites were established, and this study will also be repeated after irradiation. It is hoped that Dr. Breen will also give quantitative data on the mosses and leafy liverwort floras on the Euterpe leaves. A list giving the location of the 20 sites is included as Table 1.

Table 1

Approximate locations of rock and rock-log aggregates for algal studies.

A1. near Palm #1
A2. near Palm #4
A3. below " #7
A4. " " #9
A5. " " #11
A6. " " #12
A7. 10 meters below A6 to the left of the path.
A8. Below Palm #13
A9. " " #16
A10. Opposite Palm #18
A11. Slightly below Palm #20. The rock surface studied is just below the rock that is marked.
A12.)1) Just below and to the right of Palm 21. Collection made off stump and rotting log.
A12.(2) Off lower end of logs studied at A12. (1).
A13. Slightly above palm #24. Collections off rock surface and Tabonuco tree trunk.
A14. Below palm #26 collection from marked rock and logs in vicinity
A15. Just below palm #28. Collection off rock only.
A16. Rock on path at 10 meter point to lower center. Surface of rock heavily covered with crustose lichens which were not collected.
A17. Below palm #29, about 50 meters from ground zero, lower center.
A18. Below palm #34.
A19. Opposite palm #41 at rat marker #62.
A20. Opposite palm #45.

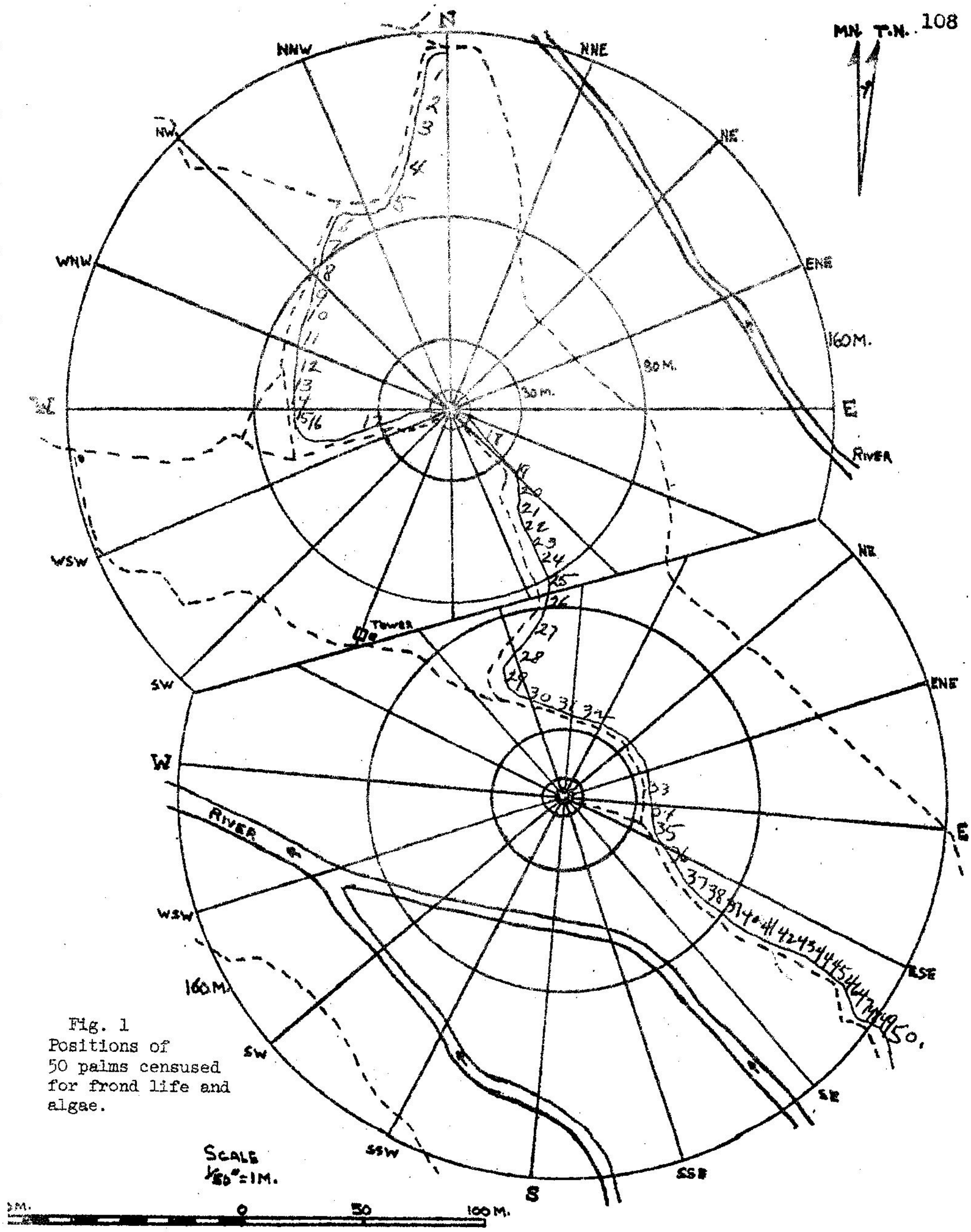

Fig. 1
Positions of 50 palms censused for frond life and algae.

REPORT ON SNAIL PROJECT

by Harold Heatwole

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Introduction

It is expected that radiation will cause a number of changes in the forest at El Verde. The effect upon snails may be direct or indirect. The former category may include effects upon viability, growth rate, or pattern of shell growth. Differential effects on different age classes might occur. In order to evaluate such direct effects several approaches have been taken: (a) pre-irradiation growth studies have been made for comparison with similar ones to be made after irradiation, (b) individual snails various distances from the source have received dosimeters, and (c) incidence of abnormal shell growth has been recorded. This study is restricted to snails of the family Camaenidae. That part dealing with direct effects has been carried out on 3 species, Caracolus carocolla, Polydontes acutangula and Polydontes luquillensis, chiefly on the first-mentioned as it is by far the most abundant in the El Verde region. In addition to the El Verde site, supplementary studies were carried out at the El Yunque Biological Station.

Indirect effects of radiation may include influences upon the distribution of snails in the area through changes wrought in the vegetation which in turn affect microclimate, food supply, etc. To evaluate such effects a comparative ecological study of camaenid snails was initiated.

There are six species of camaenid snails in Puerto Rico, one of which (Zachrysia auricoma) was probably introduced from Cuba and is not included in this study. C. carocolla is very abundant in the moist forests of the central mountains and is also present in lowland forests. It is not found in open woodlots or on roadside trees in the lowlands. In such situations it is replaced by C. marginella and Polydontes lima which also penetrate the higher altitudes along roadsides and in heavily disturbed areas. On some magotes C. marginella and C. carocolla are found together.

P. acutangula, a resident of the higher altitude forests, seems at least on casual observation, to be a canopy dweller which has secondarily made use of hibiscus hedges and similar vegetation in the more open areas. It is not very abundant. P. luquillensis, a still less common species, seems to be ecologically similar to C. carocolla although it is restricted to the rain forests of the eastern mountains.

Thus, the more open areas expected to be created by radiation might provide unsuitable habitat for C. carocolla and P. luquillensis, but cause conditions favorable for P. acutangula, which might therefore replace C. carocolla on shrubs in part of the irradiated zone. A less likely possibility is that C. marginella and/or P. lima may be able to reach, and become established in the area disturbed by radiation.

Dosimetry

Fifty individually-marked snails, at varying distances from the radiation souce, were provided with dosimeters by gluing them in the crevice between two whorls and then covering them with black electrical tape. An attempt will be made to recover these after irradiation.

Incidence of Abnormal Shell Growth

Three of the 431 C. carocolla which were marked at El Yunque had an abnormal growth pattern of the shell involving a slight displacement of the whorls. This displacement began when the snail was about half grown, the whorls becoming progressively more offset with age. No such shells were encountered in the more than 600 individuals marked in El Verde.

Home Ranges

In both areas combined, over 1,000 snails have been individually marked. Some of these have not been subsequently recaptured. However, a large proportion have been recaptured 3 or more times and some as many as 17. Their location was plotted on amap each time they were captured. Inasmuch as almost all recapture cata were obtained during the day, the "home ranges" thus plotted simply outline the area which the snail uses for its diurnal inactive period. At night they leave this area and forage, returning again the following morning. Thus the true home range is greater than the areas shown here.

Home ranges fall into 3 patterns. One of these is for the snail to always be found on the same tree, small portion of a building, or on one of several trees in close proximity to each other (Fig. 8 and 9). Another common pattern differs in that one or two recaptures may occur away from the area in which the snail is usually found. Afterwards it will be found back at the original site (Fig. 10). A third pattern consists of snails occupying one area for a long time and then moving to a new site where they subsequently remain. This was found to occur after such disturbance as the painting of a building, the wall of which was included in the animal's home range.

The above generalizations concerning home range is applicable only to adults. Data on the juveniles are now being worked up. Thus far the indications are that they do not limit themselves to as restricted an area as do the adults.

After irradiation we plan to follow the movements of animals which might leave the irradiated zone and establish home ranges elsewhere.

Habitat Selection

Individuals of C. carocolla are not uniformly distributed throughout the forest. They are less abundant on the steeper slopes and they tend to inhabit particular trees. Some trees had as many as 19 snails on the trunk at one time whereas other trees only several feet away had none, nor did they ever have any during the study. The data are now being analyzed to see if suitability for snails is related to taxonomic category, bark texture, or size of tree.

The young and adults occupy different situations; the former tend to spend the diurnal inactive hours under the leaf litter, stones, or logs whereas the adults tend to hang on tree trunks. During the drier months, even the adults may seek out refugia such as tree holes or bromeliads. These statements seem to be true for all species involved in the study. Quantitative data are available for C. marginella. On 31 December 1964, objects on the ground were lifted and the diameters of all snails beneath were measured and compared to the diameters of those hanging on the trunks during the same sampling period. The difference in habitat between young and adults is evident from Fig. 11.

Population structure

Inasmuch as juveniles and adults spend the inactive part of the day in different places, data on size obtained during the home range study are not reliable for estimating the size structure of the population. In order to circumvent this difficulty a search was made by flashlight on humid nights of the concrete walls bordering the road in the rain forest at El Yunque. Under such conditions all snails were actively foraging, and being on a smooth surface, snails of all sizes could be easily detected. For a given sample, all individuals observed were measured until about 100 individuals had been captured. Each snail was released near its capture site.

In November 1963 size classes were rather evenly distributed without well defined concentrations of individuals in any particular size range, a condition which persisted in the February 1964 sample (Fig. 12). However, by May 1964, after the early spring period of growth, there were relatively few snails in the smallest size classes and bout half of the population consisted of adults. By the end of the year, probably through mortality of many adults, the nearly uniform size distribution was reestablished. It is necessary to continue these samples, at more frequent intervals in order to verify the existence of this seasonal change in population structure, describe it more accurately, and possibly to relate year-to-year differences with environmental conditions.

The breeding cycle of these snails is not known in detail yet. However, of the 13 copulations observed in the field, all occurred in the period between 31 March and 15 June except for 2 in January, one in February, and one in December. Most of the egg clutches were found in November and December.

During 1965, monthly collections will be made in El Yunque for determining the condition of the gonads. These will be correlated with monthly samples of population structure.

Critical Thermal Maxima

Eleven C. carocolla and an equal number of C. marginella were acclimated for 1 week at 20° ± 1°C and in nearly saturated air. They were then individually subjected to a determination of the critical thermal maximum by placing each one in a glass jar which was then closed with a 2-hole rubber stopper. Through one hole a Schultheis quick-registering thermometer was inserted whereas a glass tube permitting passage of air was inserted into the other. The jar was then attached to a weight and submerged in a water bath containing a bubbler to cause mixing of the water. It was then heated, raising the temperature 1° at a time and them maintaining that temperature for 5 minutes before raising it again. Soon after heating began a snail would become active. Two end-points were used, (1) when the snail retracted its body and fell from the wall of the glass jar on which it had been attached, and (2) when it failed to respond to a tactile stimulus when tested at the end of each 5 minute period subsequent to having reached the first end point.

The two species were remarkably similar. The range in end point No. 1 was 35° - 40°C (mean 37.4°C) for C. carocolla and 33° - 40.5° (mean 38.3°C) for C. marginella. That of end point No. 2 was 42° - 45°C (mean 43.2°C) for C. carocolla and 42° - 47°C (mean 44.2°C) for C. marginella. Thus, differences between the CTM's of these two species, if real, are very slight and probably of little ecological significance. However, regression of CTM on size gave a straight line with a positive and significant slope for both species and it seems that larger individuals can withstand higher temperaratures than smaller ones. More data are being collected on this point for use in interpreting possible differential responses of the young and adults in the field. In addition, the other species will be tested as material is available.

In the field, body temperatures of 24 C. marginella ranged from 26.5°C to 35.5°C, the higher values occurring in animals directly exposed to sunlight. These latter were within the range of temperatures at which animals acclimated at 20°C drop from the substrate.

Body temperatures of 17 C. carocolla in the field were much lower (19.2-23.6°C), although it was difficult to find individuals in bright sun. It is important to get temperature data on rowland C. carocolla. In the lowlands this species is less arboreal and is commonly found in leaf litter and under debris. Perhaps it avoids the temperatures to which C. marginella is subjected.

Only 2 body temperatures of P. acutangula were available; they were 20.6° and 21.5°C. In most instances body temperatures in all species were slightly above substrate temperatures and were about the same as air temperatures. Exceptions were C. marginella in sunlight. They were warmer than either air or substrate by several degrees.

Survival time under different thermal conditions

Snails show seasonal periods of relative inactivity, related to moisture conditions. The length of time a snail can remain in a refugium continuously will depend upon the length of time it can go without feeding. This in turn depends on the energy sources stored in the body and the rate at which they are used up. The latter is greatly temperature-depndent and areas with high temperatures may not be suitable for a species which uses up its energy reserves rapidly and therefore be unable to "wait out" unfavorably dry periods.

A number of C. carocolla were collected near La Mina, P. R., and transported to the lab where they were acclimated for 8 days at a temperature of 20° ± 1°C in closed glass aquaria with about 1 cm of water in the bottom to to provide a relative humidity near saturation. During this period all of the snails emptied their digestive tracts completely inasmuch as no defecation occurred during the post-acclimation part of the experiment.

After acclimating, the snails were divided into two groups, with approximately the same size distribution. One group (52 individuals, omitting several which ate some paper during the experiment) were maintained under the acclimation conditions (20°C and about 100% rh) without food until all were dead. The second group (69 individuals) were treated differently in only one respect. They were transferred to a cabinet at 30° ± 1°C. The lights usually were turned on at 0800 and off at 1700. Departure from this schedule was the same for both groups.

Figure 13 shows the survival time at the two temperatures related to snail size. Two facts are evident. First, survival time was greater at 20° C than at 30°C and second, the larger (older) snails survived longer than smaller (younger)ones. This effect was more pronounced at the lower temperature. The first is undoubtedly related to the effect of temperature on metabolic rate and the second probably because young individuals have higher metabolic rates than older ones at a given temperature. Metabolic studies would be valuable in interpreting these data.

All but one snail (both temperatures) survived more than 2 weeks, which is probably longer than any continuous period of unfavorable conditions likely to be encountered in the El Verde site and perhaps in the lowlands as well (conclusion pending analysis of environmental data and better definition of tolerances of these snails to moisture conditions). For comparison, a study was made on C. marginella. Only adults (24 at 20°C and 44 at 30°C) were used.

Survivorship curves for the adults of both species are presented in Figure 14. C. marginella tended to survive slightly longer at 30° than C. carocolla. Although the difference was not great, it suggests either relatively greater energy reserves or lower metabolic rate at that temperature than is true of C. carocolla. Of greater interest is the fact that survivorship in C. marginella was not much better at 20°C. This the latter seems much better adapted than the former to this low temperature, a phenomenon reflected in their altitudinal distribution. The relatively poor survival of C. marginella at 20°C may reflect an effect of low temperature on viability operating in some way other than through metabolic depletion of energy stores.

An incidental observation resulting from this part of the study was that C. carocolla seems to be able to utilize cellulose as food. Between 95 and 100 days of food deprivation (20°C), the snails that were still alive ate part of a 3 x 5 file card which was inadvertently left in their aquarium. They lived much longer than expected on the basis of the shape of the rest of that, and the other, survivorship curves (Fig. 14).

Food Analysis

Fecal material from both C. carocolla and C. marginella has been collected and preserved. It has not yet been examined to see if identifiable elements are present.

Prospectus

I propose to (1) complete analysis of the data already collected, (2) expand and complete the current studies as mentioned in the text. and (3) initiate several new phases. One of these will consist of behavioral studies, and will include responses of the various species to gradients in temperature, humidity, and soil moisture, as well as correlations of activity period in the field with environmental conditions. Some data have already been collected on the latter part. A second phase will consist of a comparative study of the moisture relations and will involve measurement of water stored in the mantle cavity, rates of water loss under controlled conditions (comparing estivating and non-estivating snails) and changes in body water content. This part has not yet begun although equipment for it is now available.

Fig. 1. Growth of Caracolus caracolla at the El Yunque study area.

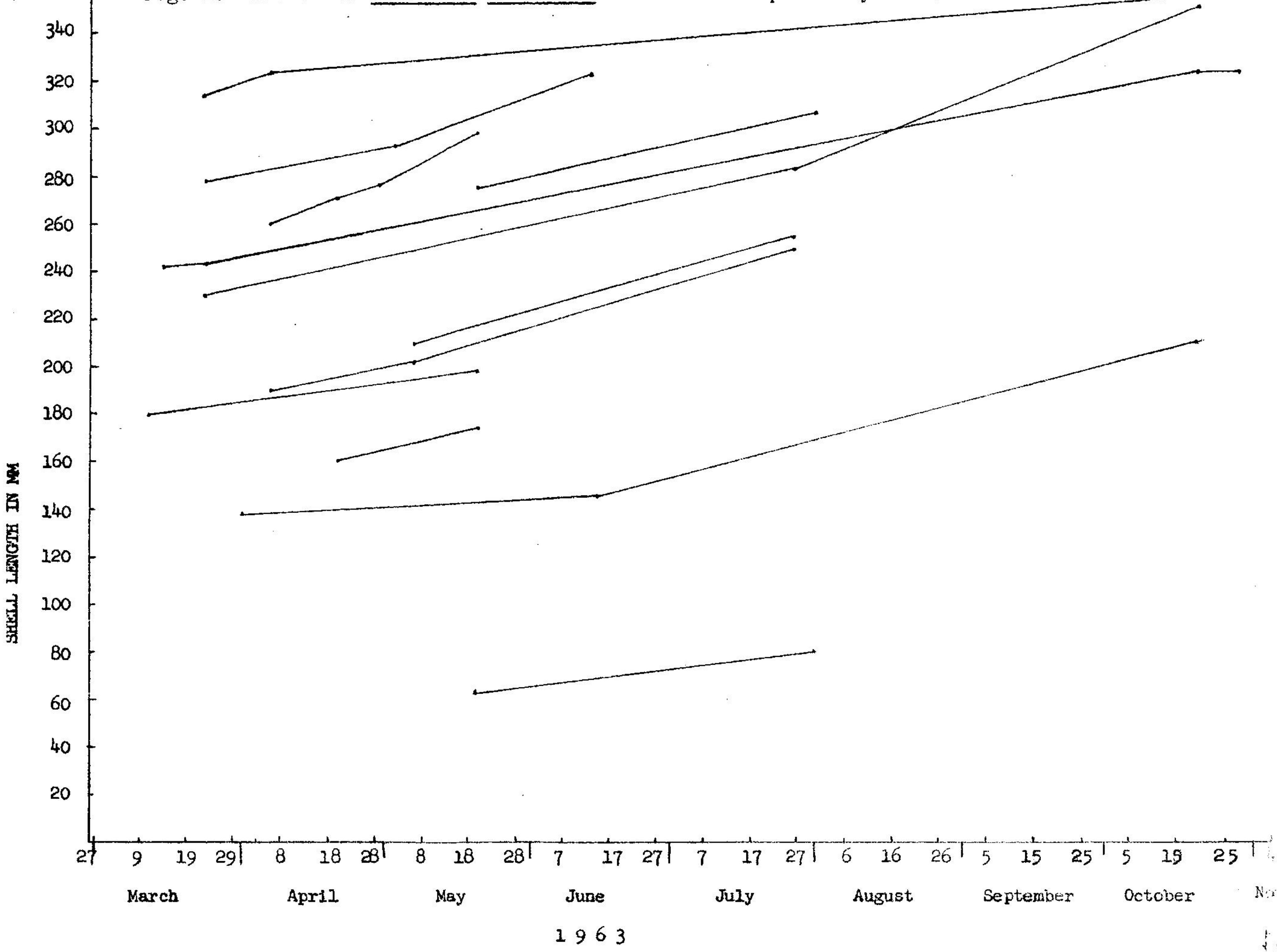


Fig. 2. Growth of <u>Caracolus</u> <u>carocolla</u> at the El Yunque study area.

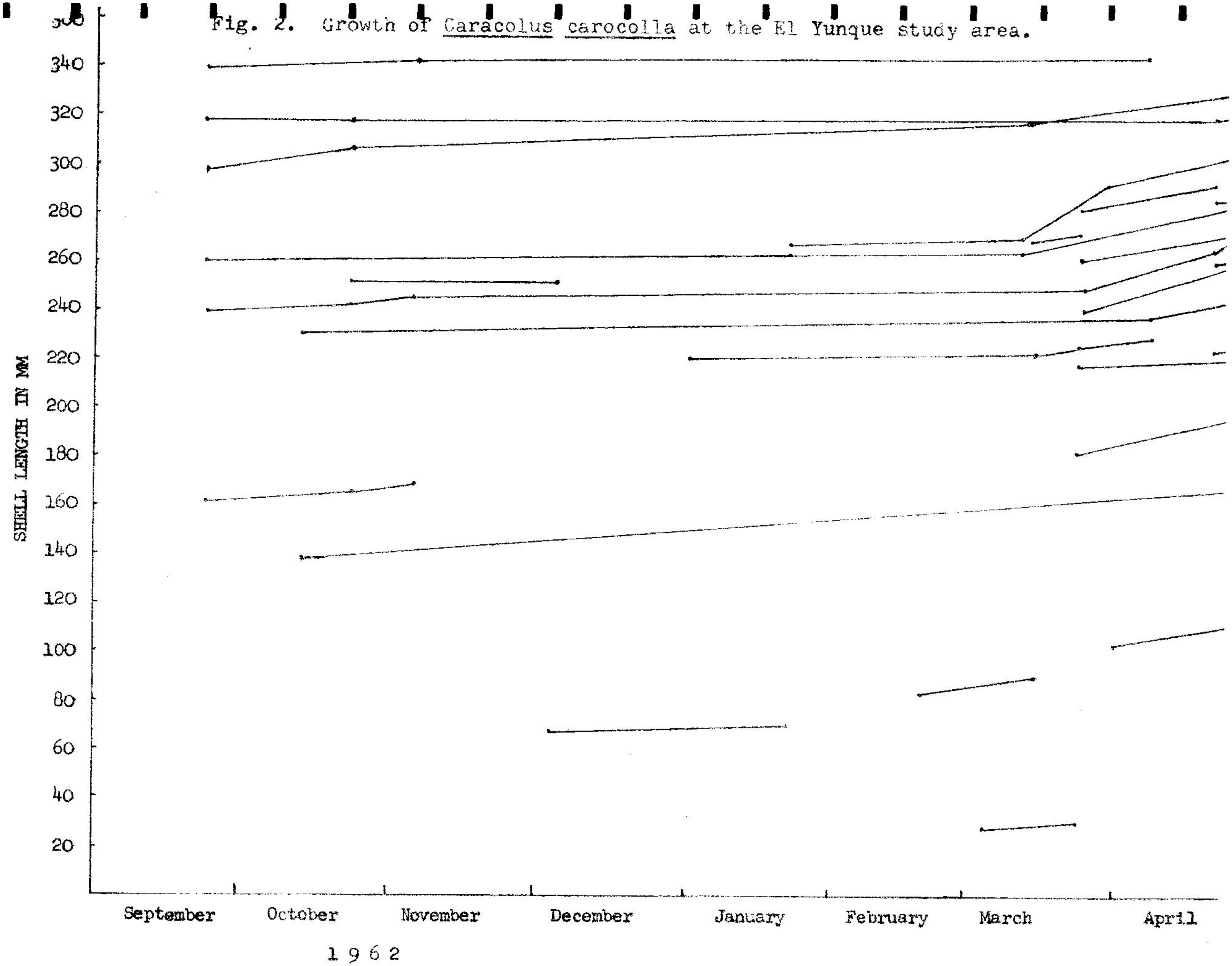


Fig. 2 (continued)

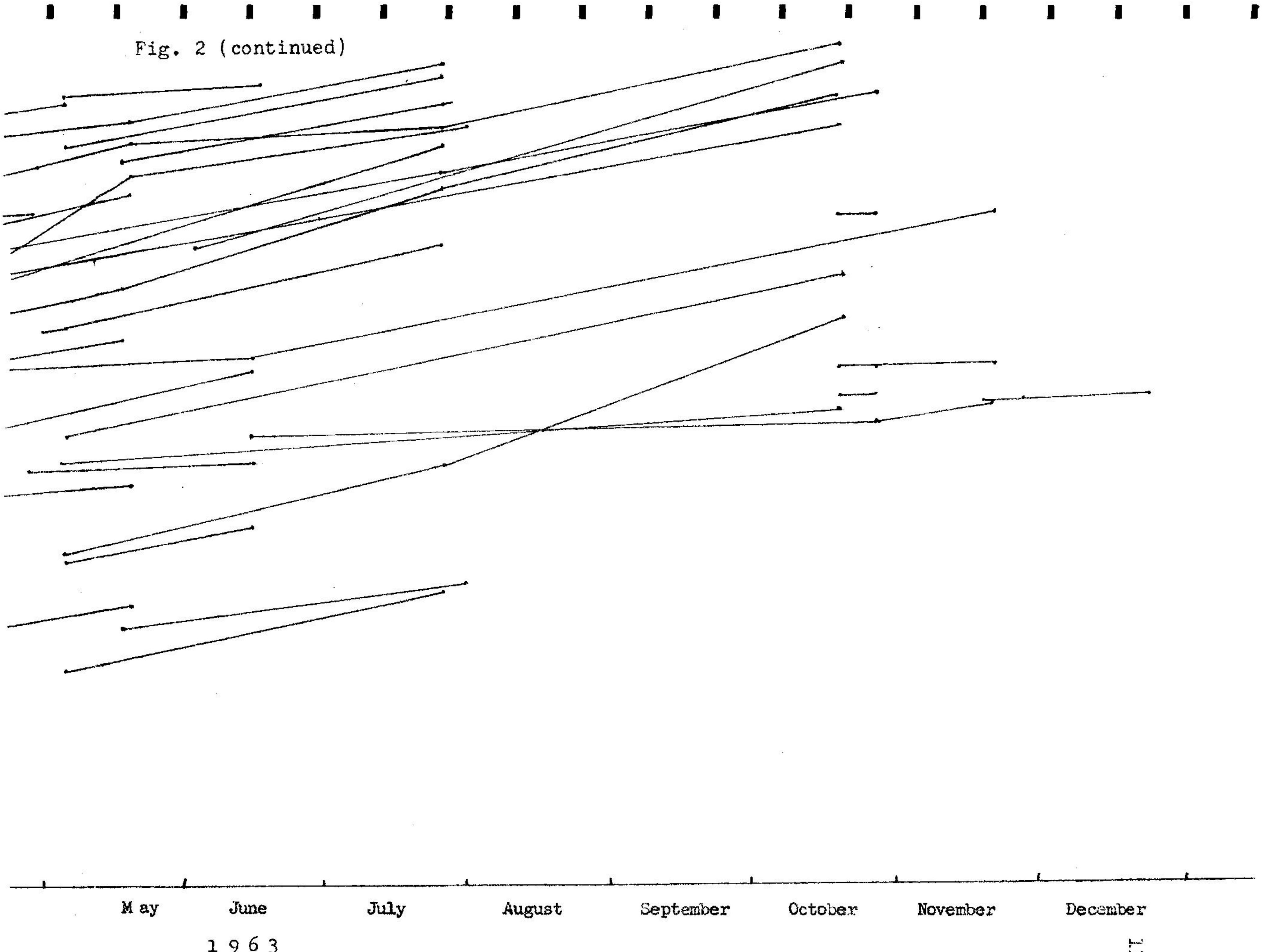


Fig. 3. Growth of some of the *Caracolus caracolla* in ... radiation center at El Verde

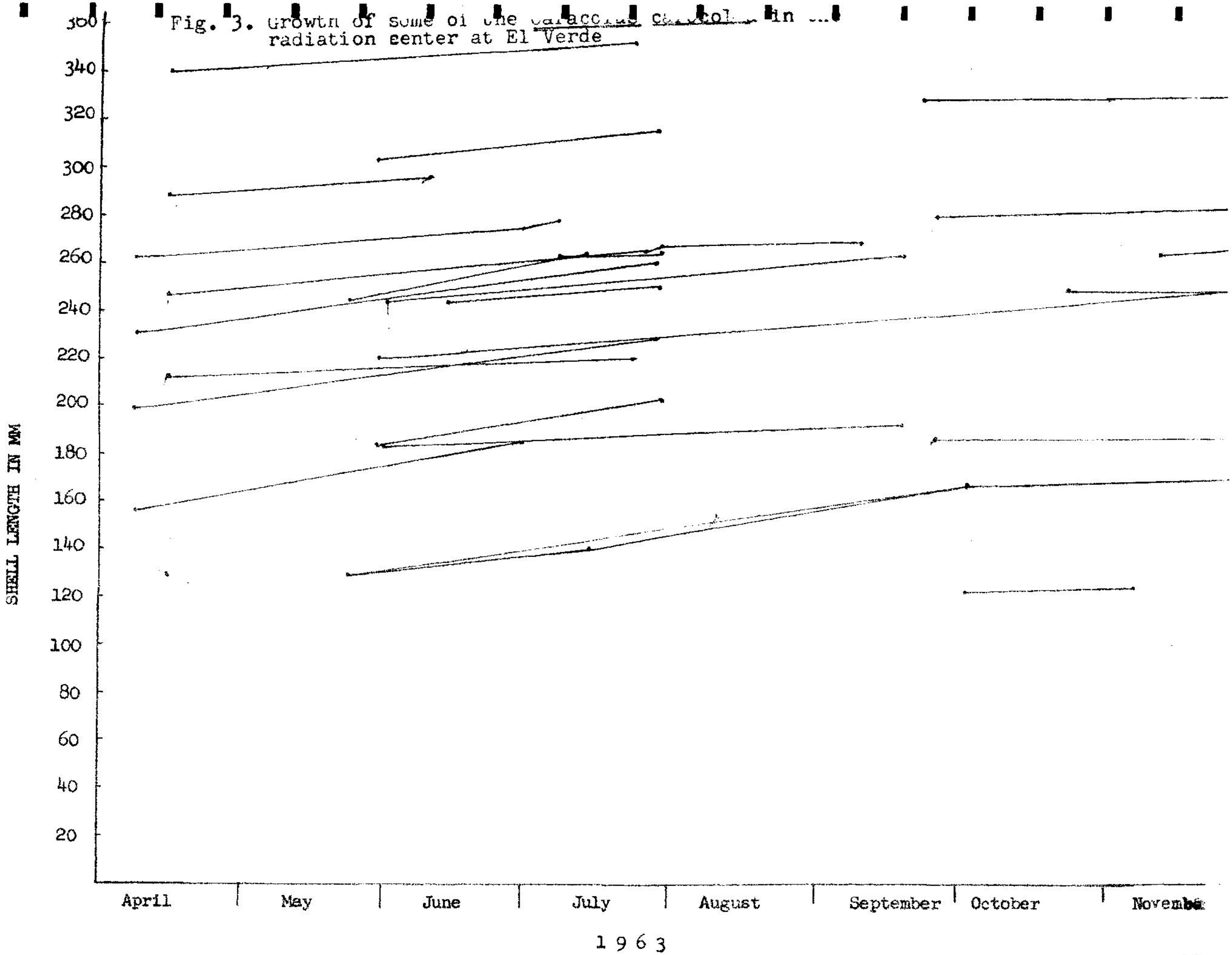
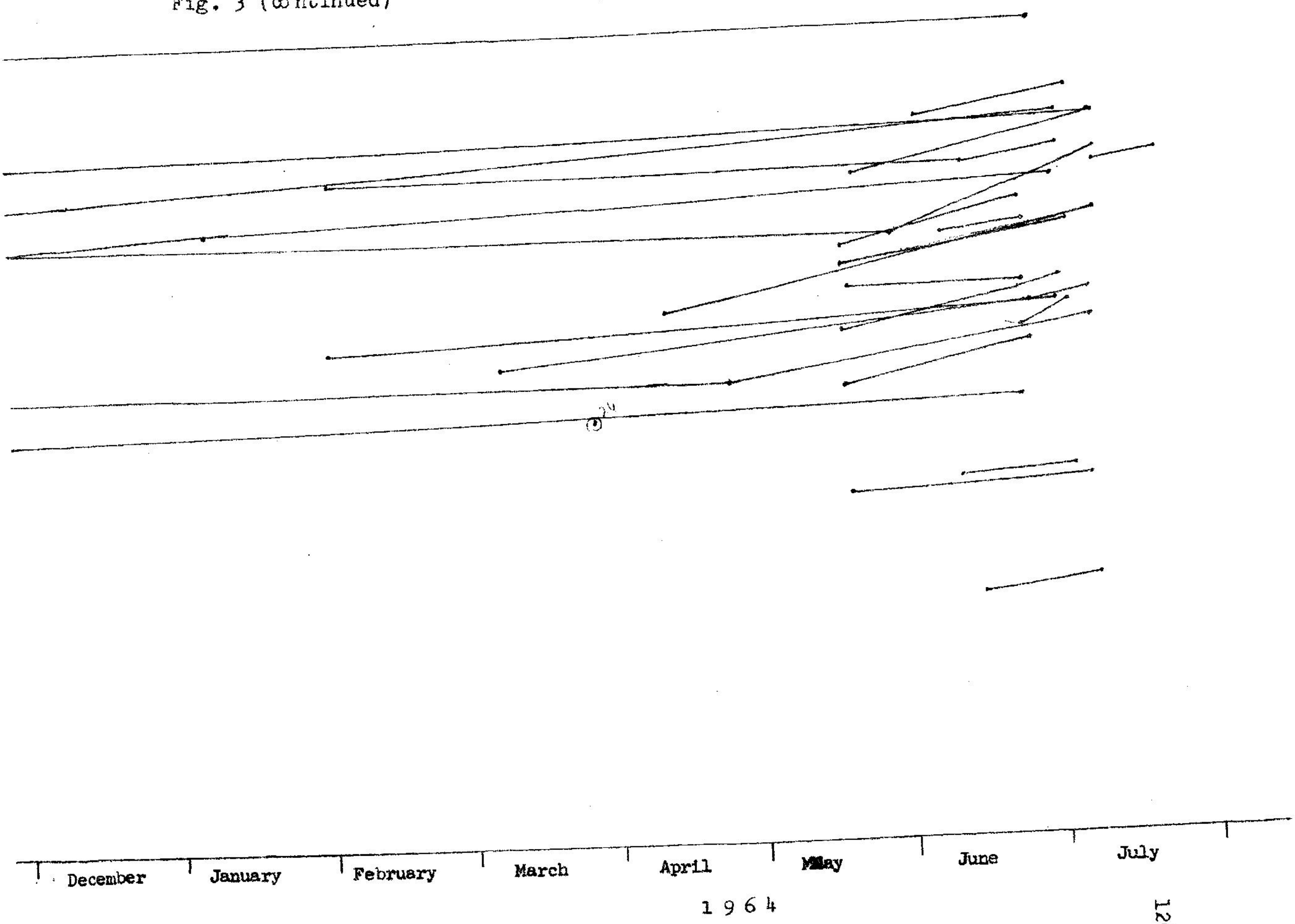


Fig. 3 (continued)



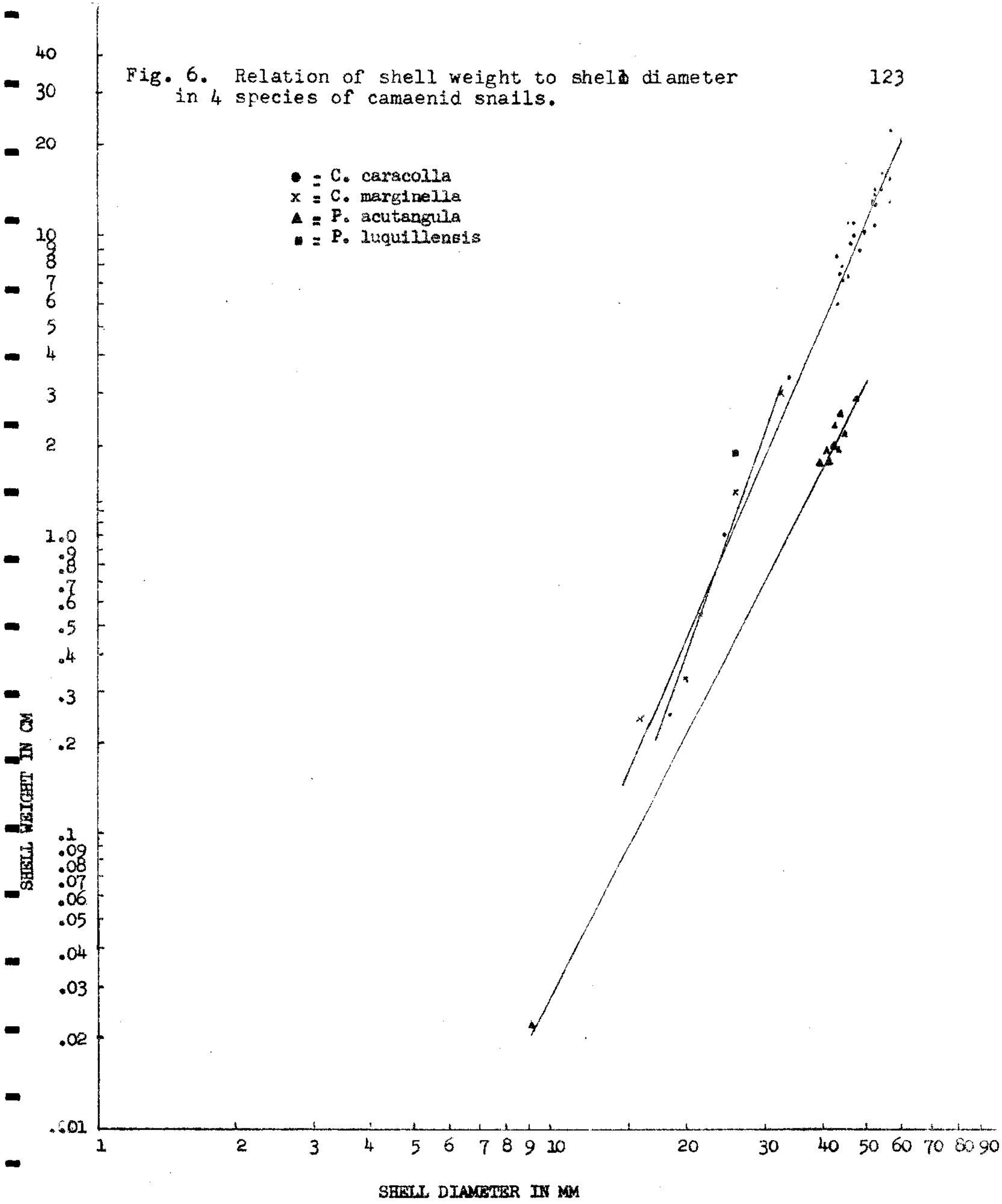
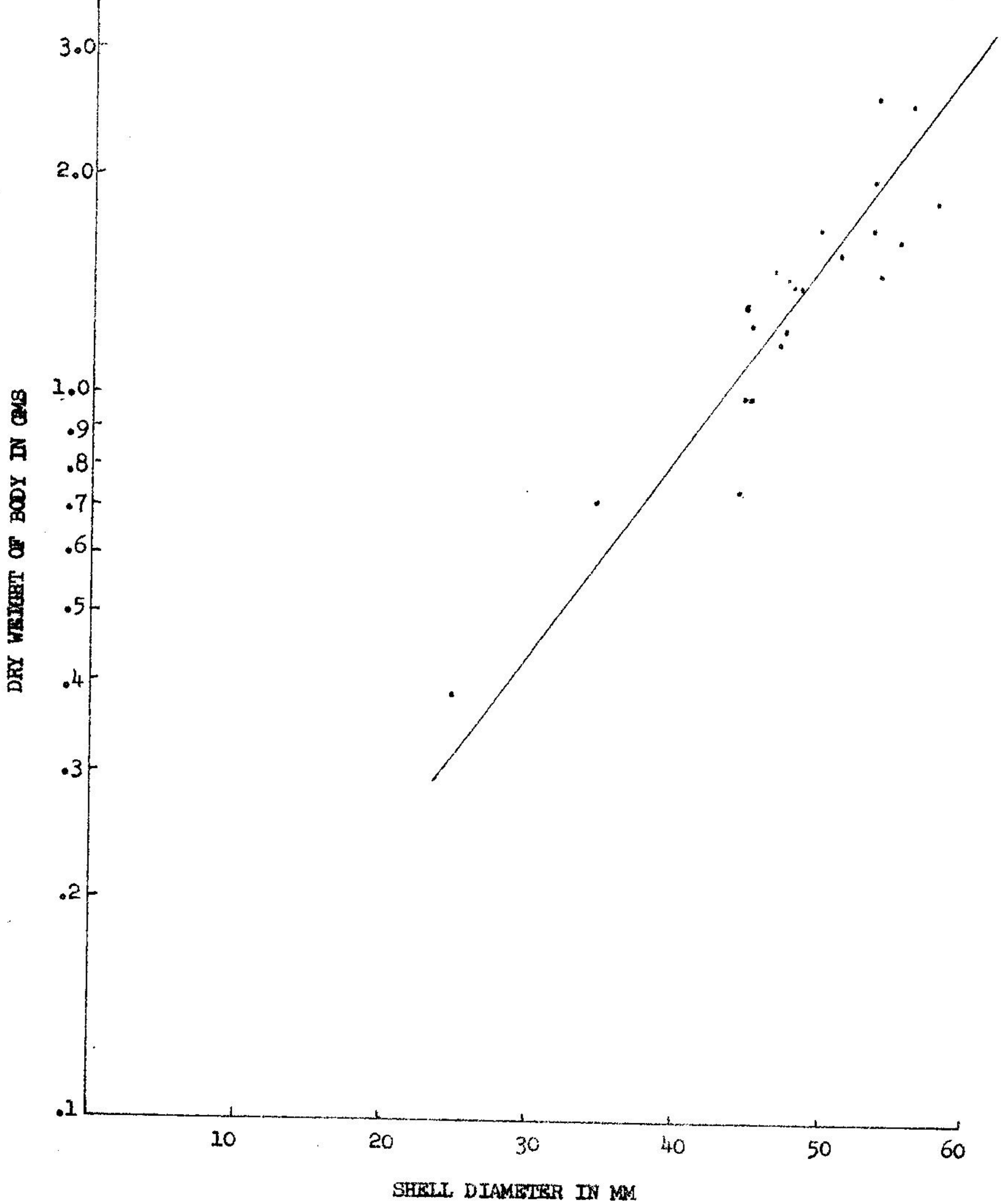


Fig. 6. Relation of shell weight to shell diameter in 4 species of camaenid snails.

Fig. 7. Relationship of body dry weight to shell diameter in Caracolus carocolla



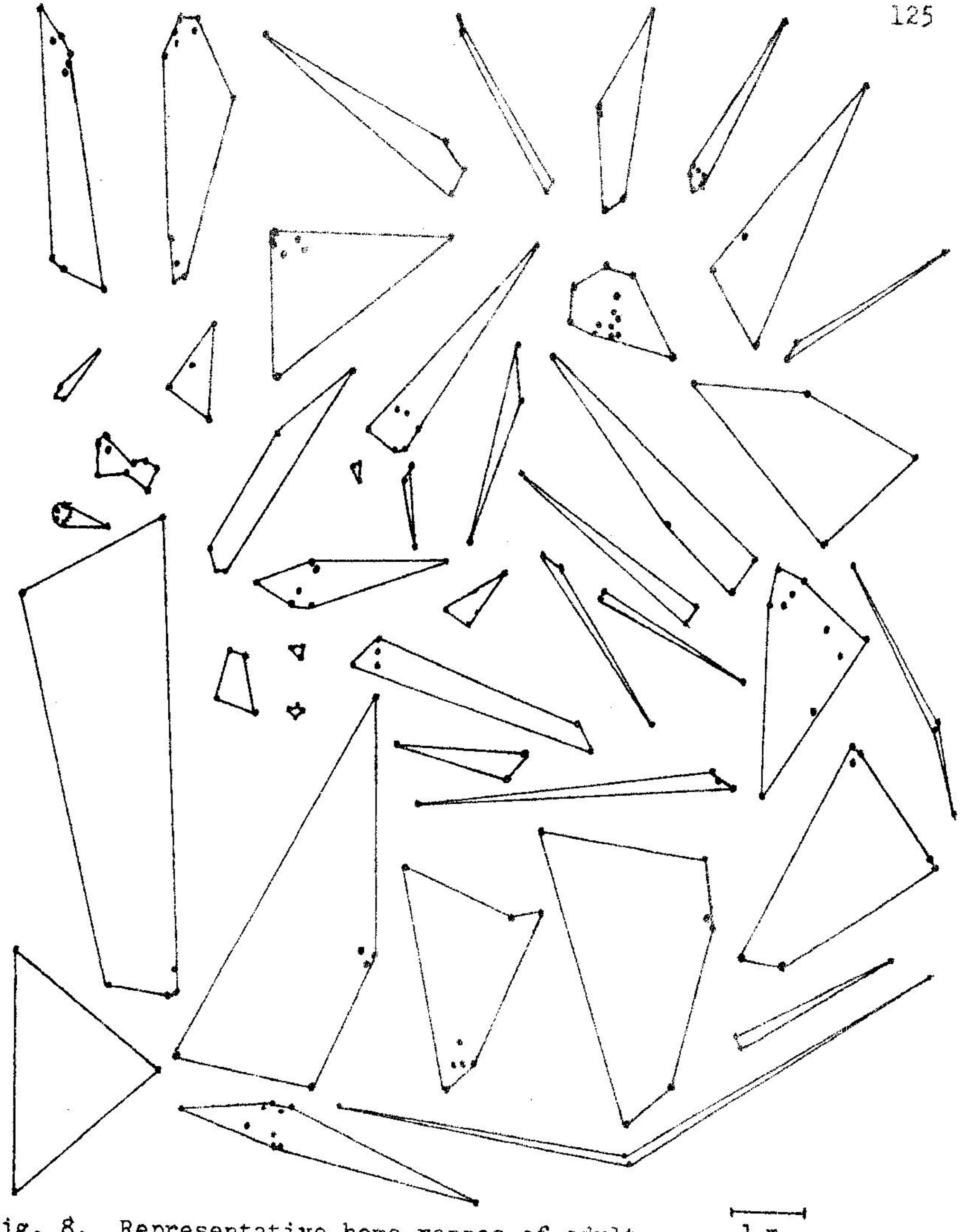
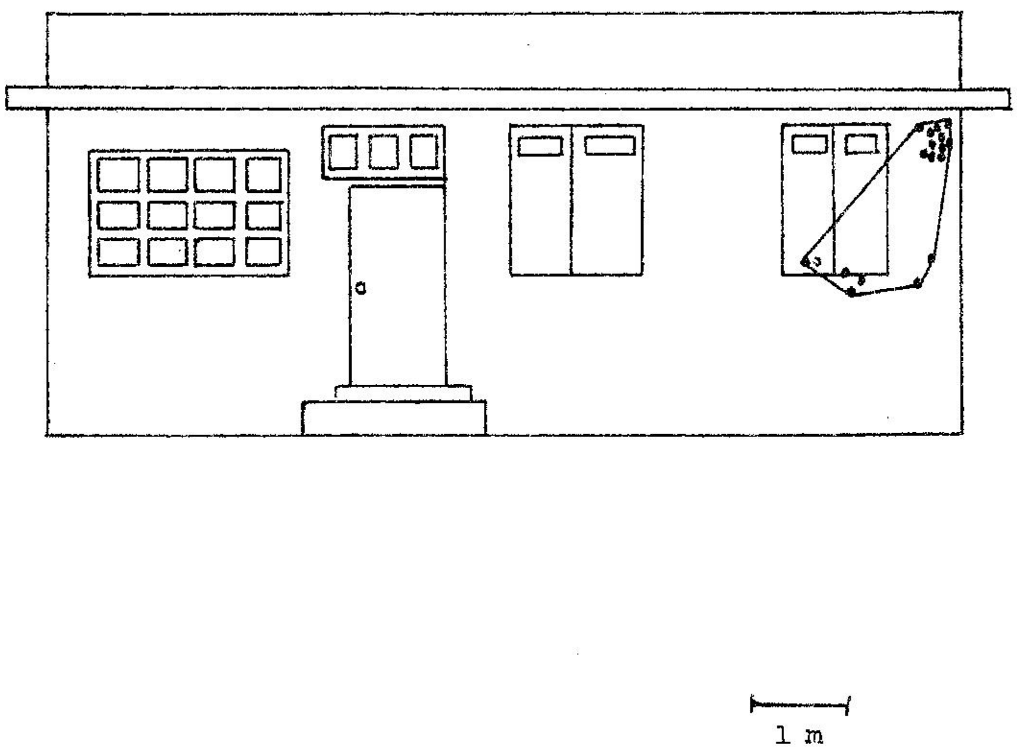


Fig. 8. Representative home ranges of adult *Caracolus carocolla* during the period from September 1962 to December 1964. Dots represent map locations without considering the height of the snails on trees.

Fig. 9. Homw range of an adult *Caracolus carocolla* at the El Yunque Biological Station between 15 September 1962 and 31 July 1963.



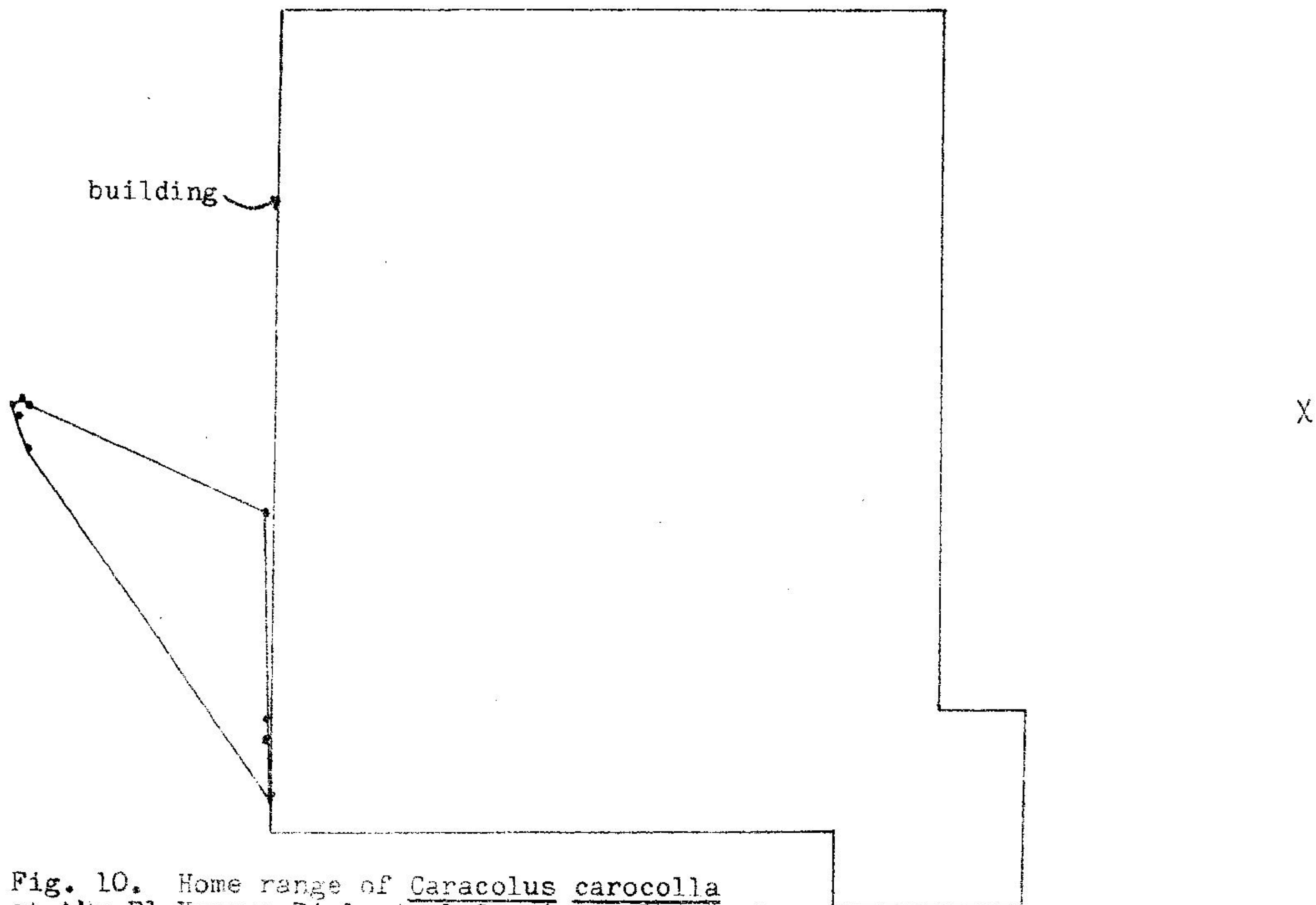


Fig. 10. Home range of <u>Caracolus carocolla</u> at the El Yunque Biological Station. The enclosed area represents its home range which it occupied from 23 October 1962 until 10 June 1962 at which time it was found at the location marked x. On 28 July 1964 and subsequently it was back in its home range.

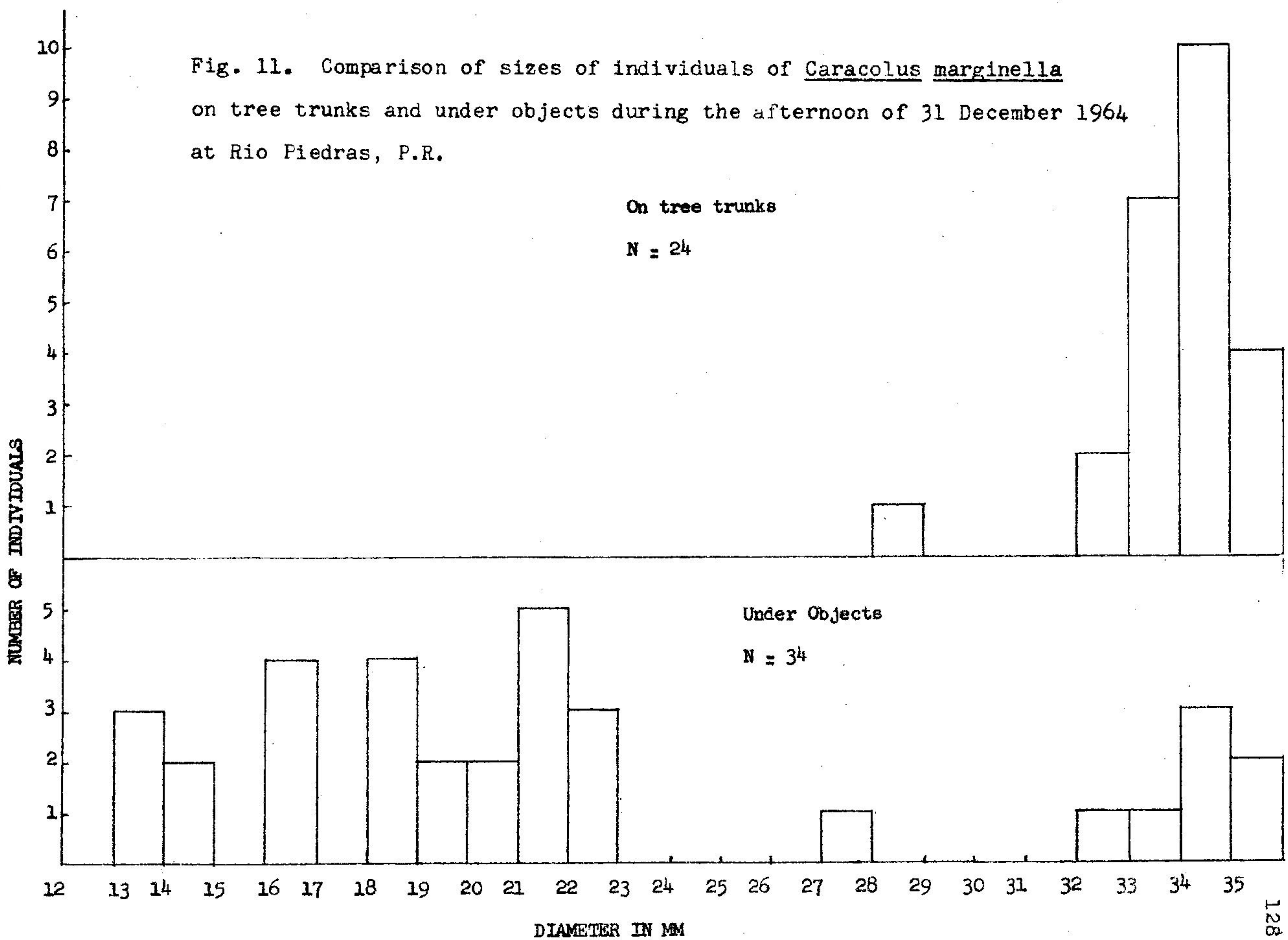


Fig. 11. Comparison of sizes of individuals of <u>Caracolus marginella</u> on tree trunks and under objects during the afternoon of 31 December 1964 at Rio Piedras, P.R.

Fig. 12. Population structure of Caracolus carocolla at different times of the year. Cross hatching signifies adults.

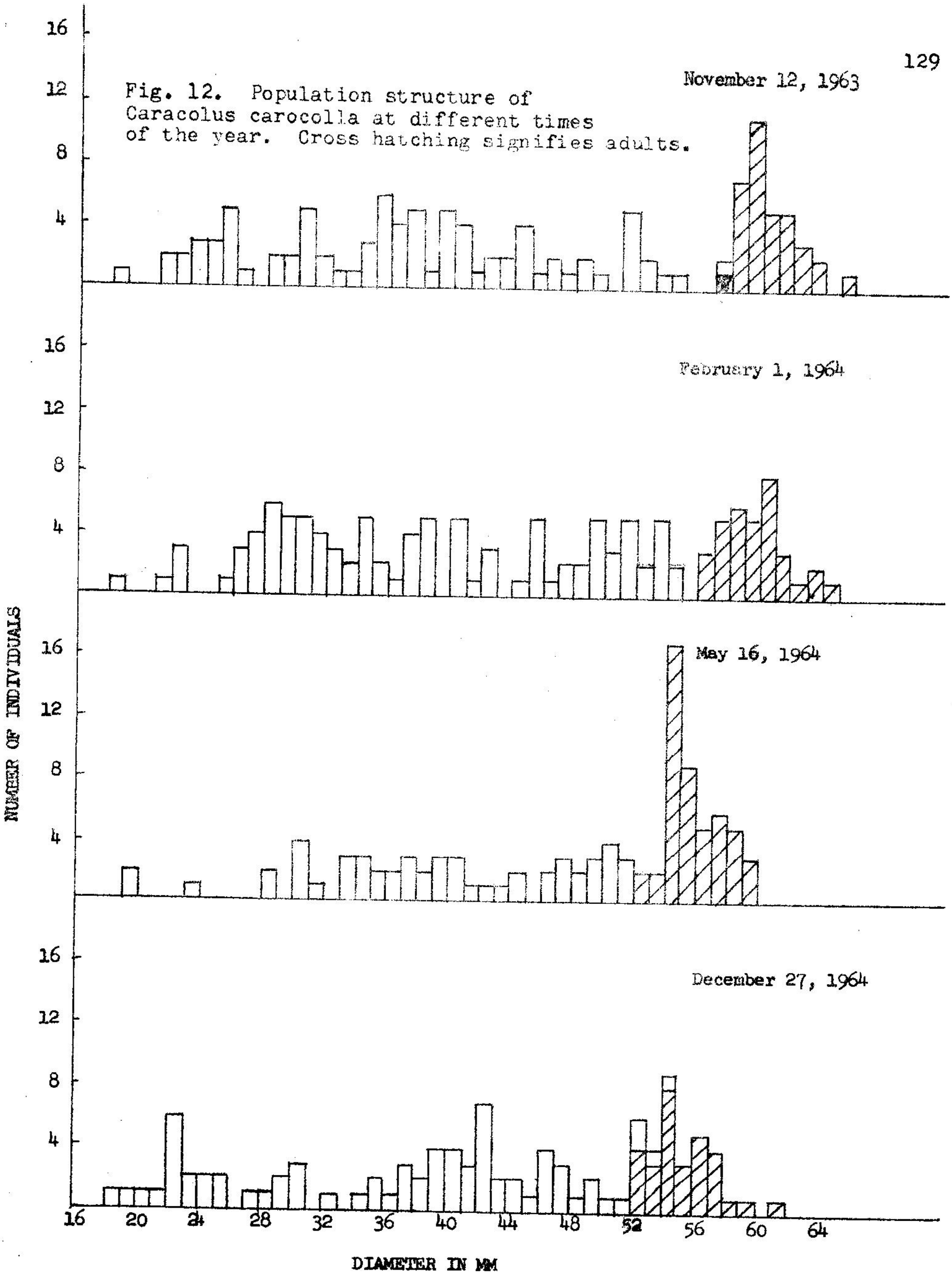
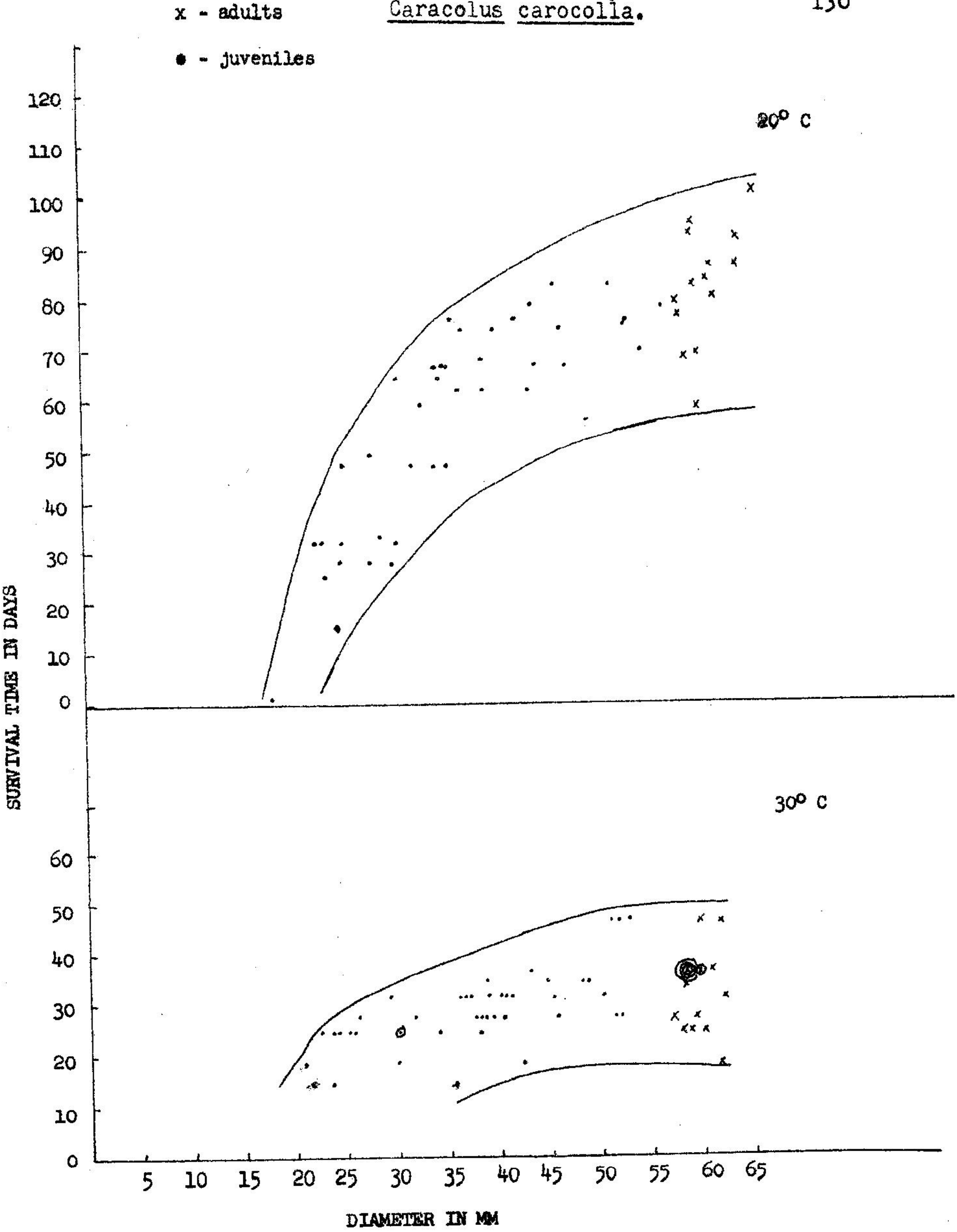


Fig. 13. Relation of snail size to survival during food deprivation at different temperatures by *Caracolus carocolla*.



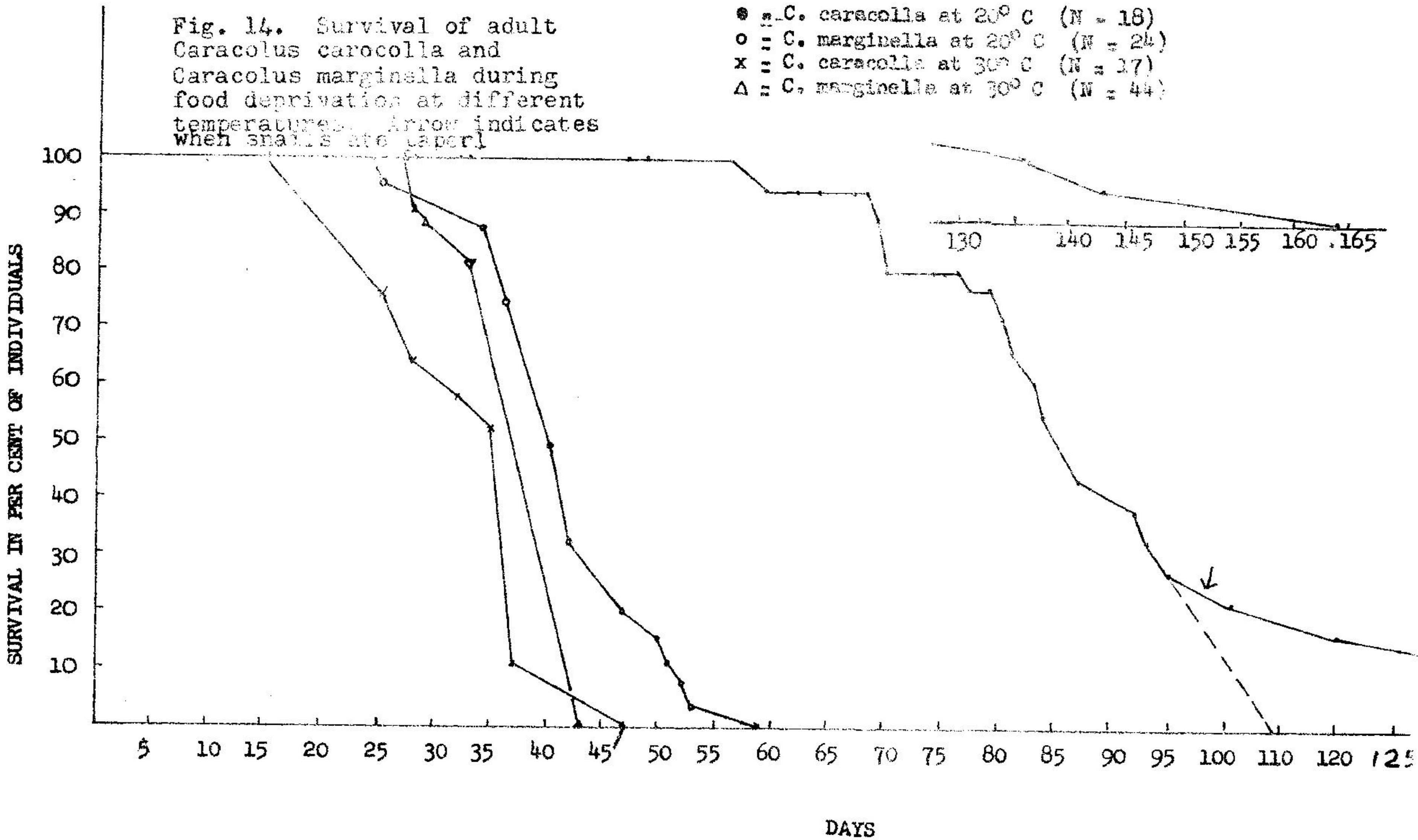


Fig. 14. Survival of adult Caracolus carocolla and Caracolus marginella during food deprivation at different temperatures. Arrow indicates when snails ate paper!

Preliminary Report

by

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Forty-two water samples were collected in and near the experimental area in the forest at El Verde Experimental Station, Luquillo National Forest, Puerto Rico. Most of these samples came from the leaf axils of Bromeliads, a few came from leaf axils of the Screw Pine, Pandanus, and one each from a depression in the soil of the forest floor, a hole in a rock near a stream, and a tree hole. The water was derived from rain. Only the rock hole and Bromeliads of samples 10 and 11 had had any chance of previous contamination by stream water. All of the samples were examined the day of collection under 30X magnification and organisms identified as far as possible. A compound microscope was used to survey selection of the samples, and in all but two instances this was completed by the second day after collection (one sample was finished on the third and another on the fourth day after collection). Tables 1 and 2 list the organisms found(not included in mimeographed report). The average number of organisms seen under 30X in samples from Bromeliads was 6.2. The range was from 1 in a plant which contained only a few drops of water to 11. The pool on the forest floor, which had much greater volume and possibly greater environmental diversity, had 9 different kinds of organisms; the rock hole, which held about the same volume of water as did the larger Bromeliads sampled, had 12 different kinds. The presence of Paramecium and the Cladoceran in this rock hole is probably the result of occasional flooding of the hole by a stream. Three of 31 plants had as many or more kinds of organisms recognizable under 30X as the pool. This may be due to greater environmental diversity of the pool, lessened dispersal problems, greater volume and surface area, and/or "more favorable" conditions, each with unknown influence. The rock hole, for which there is good evidence for flooding, contained 12 different kinds of organisms including at least two of which were found nowhere else. This is good evidence that dispersal mechanisms for all the species in the stream are not sufficient to take them quickly or at all to Bromeliads. The average number of different kinds of organisms observed in water from Bromeliads with magnifications up to 1000X was 10.3 with a range from 4 to 14. Comparable figures for the forest floor pool and the rock hole are 19 and 13 respectively. This pattern is consistant with that seen under lower magnifications.

Totals of number of kinds of organisms for all samples from the Bromeliad, Guzmania were analyzed to determine if there was detectable change in number as a function of height of the plant above the ground. Rank difference correlation coefficients of height with number were -0.130 for samples examined with the dissecting microscope and -0.137 for those examined with the higher magnifications. This shows that there is little if any influence of height on number of organisms in plant held rain water. The maximum variation in number of organisms which might be caused by or correlated with variation in height is estimated by the square of the r_d, and is 1.9% and 1.7% respectively. These low values show that the mechanisms by which aquatic organisms get to water within these Bromeliads, at least within the lowest 20 feet or so of the forest, are efficient and perhaps are equally effective at all levels below this height. It is unlikely that the mechanisms are more efficient at some height or heights than at others, but with the efficiency great enough, even at its lowest, to produce near maximum colonization of all Bromeliad waters. If maximum colonization of all Bromeliads occurred, a large fraction of the pattern of occurrences or absences of various species would be the result of direct inter-species interaction which would produce much more highly developed patterns of associations than those found and described below. Measure of colonization rate starting with containers free of organisms should give information concerning relative rates of species establishment in environments similar to Bromeliad waters. Such data also will give information on recovery rates following community disruption or destruction by ionizing radiation.

Table 3 gives the distribution of the most common organisms found in Guzmania as a function ofheight from the ground. None of these distributions hint at a pattern with respect to occurrence and distance from the ground.

Figure 1 gives Cole's association coefficient $\pm 2\ \sigma$ for pairs of organisms from Guzmania common enough to warrant calculation of association coefficients. Of the 21 associations, all are positive (or zero) except for 3. Each of the negative associations involves moaquito larvae as one member of the pair. In addition, the only two zero associations involve mosquitoes as a member of the pair; however, average number of organisms for water with and without mosquitoes does not appear to be different.

Four of the association coefficients are significant at the 0.5% level and two more are very close to this. The significant positive association between Cyclopoid Copepods and nauplii suggests that Cyclopoids may have been reproducing more successfully than Harpacticoids when the samples were taken or, less likely, that sampling methods adequate to capture Cyclopoid nauplii were much less effective in the capture of Harpacticoid nauplii.

The positive, significant association of Tendipedid larvae with Cyclopoid copepod and Bdelloid Rotifer with Harpacticoid copepod may be real. If so the mechanism which produce the associations are not clear, especially in the case of the Tendipedid and the Cyclopoid which presumably have different means of reaching Bromeliad waters. It should also be kept in mind that in series of this size, one association on the average would be expected to be significant because of sampling chance rather than because of causal relationships.

By far the most interesting association pattern is that between mosquito larvae and the other common relatively large organisms (see Fig. 1). This suggests that mosquitoes may interfere with other organisms of about the same size, although the lack of appreciable difference between numbers of kinds of organisms in Guzmania with and without mosquitoes shows that it is not a general phenomenon.

Frequent positive non-significant association between pairs of organisms in series of isolated habitats such as the axil waters of Bromeliads occur even in the absence of direct interaction between the organisms. Some factors which might tend to result in such positive associations are:

1. Common transport mechanism
2. Common kinds of response to some events or characteristic

    a) amount of water in Bromeliad
    b) kind and/or amount of food (i.e. the number and species of tree leaves in the water)
    c) toxic effects of:

        1) material leached from leaves of some plants which might fall in Bromeliad
        2) condition of putrifaction, etc.
        3) toxic metabolities of a third organism

    d) spotty distribution of other more or less "extreme" conditions.

3. Interdependence of two or more organisms
4. Action of animal predation
5. Action of animal which efficiently removes some requirement

(Raw data tables are not included in this mimeographed report for lack of space).

List of Some of the Forest Markers

Especially for the benefit of our visiting participants who use these reports as a means of orientation, we list some of the markers which have been used in the study areas. To aid communication we ask that all marking done be concrete, aluminum, or something equally permanent and the system be cleared with the project. The positions of all the markers are added to the next report. Please do not remove any markers, even your own, since persons often make records using the designations originally put in by others.

Square White concrete posts---	Negrón	Primary Survey by Negrón	
	R	Rat trap stations-Weinbren	
	W	Leaf fall stations-Wiegert	
Round concrete posts---	Cow.	Litter bags	Cowley
	Seedl	Seedling plots	Smith
	Green	Algal palm stations-	Halicki
	Red	Palm quadrats -	McCormick
	White	Tree growth trees -	Murphy
White painted signs (1 to 11)		Photographs - Johnson & Atwood	
Aluminum tags (< 10,000, radiation center)		Basic tree tagging -	Smith
	H -	Snail trees -	Heatwole
	X-	Growth trees -	Murphy

FIGURE 1: Cole's Association Coefficient ± 2σ

		Tendipedid Larvae 14	Bdelloid	Ostracod	Harpacticoid	Cyclopoid	Nauplii
Bdelloid Rotifer	5	.063 +.168					
Ostracod	7	.036 ±.220	.063 ±.346				
Harpacticoid Copepod	4	.118 ±.154	.656* ±.502	.625 ±.632			
Cyclopoid Copepod	8	.308* ±.244	.180 ±.310	.250 ±.394	.228 ±[illegible]		
Nauplii	7	.143 ±.220	.063 ±.346	.357 ±.438	.11[illegible] ±.25[illegible]	[illegible] ±.466	
Mosquito Larvae	9	.036 ±.220	-.533 ±.894	.000 ±.358	[illegible] ±1.040 (?)	[illegible]* ±[illegible]	.000 ±.358 (?)

Progress Report for P.R.N.C.

Dr. Joe A. Edmisten

Botany Department - University of Georgia

Athens, Georgia

During mid-September of 1964 a ten day visit to the rainforest project at El Verde was made. The visit had two major objectives. The establishment of a Ph.D. research program for Robert Ford Smith dealing with the structure of the rainforest before and after radiation treatment was the first objective. The second major object was to initiate my own studies in the three following areas: (1) the analysis of the physical and chemical properties of the existing soils and parent material associated with the El Verde vegetation, (2) the histological investigation of the root tips of 34 major trees of the rainforest area in reference to mycorrhizal association, (3) autecological investigations of the germination and seedling growth of palo mato (Ormosia krugii).

Soils

The soils of the area belong to the Los Guineos clay series. Los Guineos clay is quite similar to Catalina and Cialitos soils, but is found at higher elevations with wetter, cooler climates. The soil of the El Verde rainforest area is characterized by steep or very steep relief and has a 6 to 8 inch grayish-brown slightly granular medium plastic, strongly acid surface soil. The subsoil consists of a 3 to 6 inch layer of brownish-yellow clay that abruptly changes to red plastic but permeable, strongly acid clay. This layer gradually changes at about 3 to 4 feet to lighter red more friable acid clay. Many large boulders are on the surface of the soil with as much as 50% of the surface covered with rocks. Smaller rocks (up to 10 inches in diameter) may be found throughout the profile. Under forest conditions, the soil has an excellent crumb structure which results in unusually good internal drainage for such a clay soil with as much as 60% clay sized particles. Soil samples taken in a systematic manner from 4 areas in the El Verde forest are being tested for total cation exchange capacity, organic matter content, soil separates, clay type, ppm Mg, ppm Mn, ppm Zn, ppm Cu, ppm P and ppm NO_3. Although the tests and interpretation of tests are incomplete, the following table indicates something of the chemical nature of the soil.

Table 1

		PH(1:1)		C.E.C.	Exchangeable (ppm)						Acid.Sol.
Location	Depth Inches	0.1Kcl	H_2O	Me/100g	Ca	Mg	K	Mn	Zn	Cu	P(ppm)
Upper Center	5-10	4.1	4.3	11.2	270	87	24	*	<1	T**	17
Lower Center	5-10	4.3	4.9	11.6	415	99	24	*	<1	T	14
Bob's Area	5-10	4.5	5.4	17.1	1,110	873	30	41	<1	T	6
Water Supply	0-5	4.9	5.7	16.8	1,860	771	32	40	<1	T	2
Lower Center	0-5	5.2	5.7	17.0	827	402	58	170	<1	T	6
Bob's Area	5-10	4.7	5.6	12.8	1,260	795	32	*	<1	T	4
Water Supply	0-5	4.9	5.7	19.0	1,440	711	38	40	<1	T	2
Upper Center	0-5	3.6	4.3	50.8	202	300	104	*	<1	T	21
Lower Center	0-5	4.2	4.8	22.5	810	285	96	*	<1	T	21
Bob's Area	0-5	5.3	5.7	29.1	3,840	1,515	186	170	<1	T	13
Lower Center Gully	0-5	4.9	5.3	10.4	1.200	450	58	245	<1	T	4

* Missing data
**Trace

It is of particular interest to note that most roots of trees and shrubs are restricted to a mat found on top of the soil. It is of further significance that the roots of such early succession species Cecropia peltata and Didymopanax morototoni are always at the bottom of this 4 to 5 inch thick mat and their root tips are large and knob-like with a manimum of branching. Such morphology is in keeping with the habits of early, fast growth but doubtful longivity of any one given tree.

Particle size distribution as determined by the hydrometer method described by Bouyoucos (Soil Science, 42:225-230, 1936) may be seen in Table II.

Table II

Depth Inches	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay
0-5	0.2	1.1	1.8	9.0	12.2	38.1	37.6
5-15	0.3	1.3	1.9	7.5	8.9	29.2	50.9

The parent material as represented by the existing rocks and boulders of the area has been identified as basalt by Dr. Vernon Hurst of the University of Georgia Geology Department. This basalt contains calcite inclusions as amygdoloids. One sample of rock taken from the El Verde area consisted of chert with pyrite crystalls in it. Most of the parent material is, however, dark, fine grained volcanic material classified as basalt. More detailed tests of thin sections are being made and chemical analysis will be made in the near future.

Root-tip Studies of El Verde Trees

Root-tips from 32 species of plants representing canopies and understory of the rainforest were taken in September of 1964. These roots were preserved and fixed in a solution of ethanol, acetic acid and chromic acid. Stained slides are now being prepared from the root tips for examinations relating to possible endotrophic and ectotrophic mycorrhizal associations. External examination of the roots reveal that only 1 of the 32 species of roots collected exhibit root hairs. All of the other 31 species appear to have some degree of fungus-root association. Dr. W. C. Bryan of the U.S.D.A. Forestry Laboratory at Athens, Georgia is being consulted with concerning the mycorrhizal problem. The 34 species under investigation are listed in the following table.

Table III

Buchenavia capitata	Euterpe globosa	Meliosma herberti
Casearia arborea	Ficus crassinerva	Manilkara nitida
Cyathea arborea	Hirtilla rugosa	Magnolia splendens
Cordia boringensis	Homalium racemosum	Miconia tetandra
Cananga caribaea	Ixora ferrea	Ormosia krugii
Croton poecinlanthus	Inga laurina	Ocotea portoricensis
Cecropia peltata	Inga vera	Palicourea riparia
Cyrilla racemiflora	Mayepea domingensis	Rourea glabra
Dacryodes excelsa	Myrcia deflexa	Sloanea berteriana
Drypetos glauca	Matayba domingensis	Tetramogastris balsamifera
Didymopanax morototoni	Micropholis garcinifolia	

In such an area as the El Verde rainforest, where 120 inches of rainfall per year could leach out anions as fast as they were mobilized, a fungus-root association could act as a trap. Such a mechanism has been described by Kramer in Science, 110, 8-9.

Autecological Studies of Ormosia krugii

Palo mato (Ormosia krugii) is one of the many trees which share dominance in the El Verde tropical rainforest. This species belongs to the legume family and reaches a height of 80 to 90 feet and a dbh of up to 30 to 40 inches when mature. During germination experiments, the cotyledons were not raised with the shoot so palo mato's germination is hypogeal. Four hundred seeds taken from the ground outside the study area were subjected to four different treatments. Bach germination experiment was conducted on 100 seeds in lots of ten seeds. The first treatment consisted of wrapping seeds in wet paper towels which were placed in glass jars. The jars with loose fitting tops were placed in an incubator with the temperature set at 80° F and left for 3 weeks with daily checks. The second treatment involved germination of chemically sterilized seeds in heat sterilized Sphagnum moss. A third set of 100 seeds was placed in untreated Sphagnum moss without any treatment to the seeds. The fourth set of seeds was chemically sterilized with clorox as in treatment number 2 and then coated with a commercial preparation of Rhizobium bacteria and planted **in** sterile moss. All of the seeds in moss were placed in shallow trays on tables in the greenhouse where temperatures ranged from 65° F to 80° F. The light intensity of natural light reached 2500 footcandles on the clearest days. Fortyeight per cent of the seeds in the paper dolls of the first treatment swelled and took up water in a 1 to 1 ratio to initial dry seed weight, a fact true of all seeds in all treatments. All of these seeds decayed and the remaining 52% of seeds stayed small, firm and impervious. In treatment number 2, with sterile seeds in sterile Sphagnum, 16% of the seeds resulted in seedlings after 1 month of observation. The ramaining seeds were hard, shiny and impervious. The third set of seeds with untreated seeds and untreated moss exhibited a slightly higher rate of germination (19%) but 11% of the other seeds decayed. In the fourth experiment in which sterilized seeds treated with "Nitrogen" and planted in sterile moss, the rate of producing seedlings was 36% after one month and 6% of the seeds decayed.

In the light of these studies, it appears that a biochemical digestion of the hard seedcoat of the palo mato seeds greatly aids the water uptake and sprouting of these black and red seeds.

All seedlings, regardless of germination treatment were potted in individual 4 inch pots in medium sand and divided in the 2 groups. One group was placed in a crowded greenhouse area which simulated the low light intensities of the closed canopy forest at El Verde. In this shaded area the light intensity never exceeded 80 footcandles. Both groups of potted Ormosia krugii seedling were fertilized regularly with a solution of 5-10-10. The well lighted group of seedlings were left in the area of germination where the light intensities ranged from 1000 to 2500 footcandles during the day. All seedlings had only 2 leaves at the start of this phase of the experiment and these leaves were distinctly opposite. These leaves all had distinct drip tips. All seedlings in the low light intensity area remained in this 2 leaf stage while all seedlings in the area of higher light intensity put out 1 to 3 more leaves. About 80% of these added leaves are arranged in an alternate manner on the shoot. All of the leaves, original and subsequent, are simple, entire with drip tips. Experiments are planned to test the alledged survival value of drip tips in the high rainfall areas. Studies by H.T. Odum in the forest at El Verde have suggested that many seedlings of potential canopy stature exist in a state of "suspended animation" waiting for a hole to open in the dense canopy. The differential behavior of shaded and well lighted seedlings of palo mato seem to substantiate such a theory.

The root tips collected from mature palo mato trees in the El Verde forest exhibited both ectotrophic mycorrhizae and bacterial nodules. The seedlings from all germination treatments lack both these features at the end of 2 months. Further experiments are planned in which these seedlings will be treated with soils from the rainforest area and observed closely. The existing roots on the palo mato seedlings are without root hairs, they are generally short, knobby and highly branched while in the moss but extend downward to equal about 1/3 the length of the shoot when transplanted to the sand in pots.

Dr. James Duke at Beltsville, Maryland is being consulted about the future work with drip tips, mycorrhizal and bacterial root swelling, and response to light. Dr. P. W. Richards will visit the Botany Department of the University of Georgia within 10 days for consultation.

Pre-irradiation studies of lizards and tree frogs in the Luquillo Experimental Forest, Puerto Rico[1]

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[1]These studies were supported in part by Contract AT(04-1) GEN-12 between the U. S. Atomic Energy Commission and the University of California.

Introduction

Knowledge of the influences of ionizing radiation on natural populations and communities is as important today as understanding the effects of such radiations on individual organisms and cells. The impact of ionizing radiation on man and his well-being is largely dependent upon the responses of the natural assemblages of plants and animals with which of species; alternations in the energy utilization of component populations; and changes in species diversity may have subtle--or drastic--effects on man's environment. To date, any such influences owing to ionizing radiation have been extremely subtle--except in a few highly localized areas. Studies at Brookhaven National Laboratory (Woodwell 1962, 1963; Brower, 1964) and in Georgia (McCormick and Platt 1962, 1963; McCormick 1963, Daniel 1963, McGinnis 1963, Pedigo 1963) have shown that such trivial effects may become important ones when higher levels of radioactivity are involved. Correlations between radiation dose and the severity of observed effects are known only for a few areas, and over a relatively narrow range of exposure. For most environments we have no direct measurements of such effects.

The forest irradiation experiment conducted by the Puerto Rico Nuclear Institute is designed to explore the effect of three months of chronic gamma radiation (from a 10,000 curie Cs^{137} source) on the composition and function of a montane tropical forest. The study area is located in the Luquillo Experimental Forest near the town of El Verde--about 25 miles east of San Juan--at an elevation of approximately 1500 feet above sea level. The dominant tree in the forest is the tabonuco (Dacryodes excelsa), but Sierra palm (Euterpe globosa), cecropia (Cecropia peltata), palo colorado (Cyrilla racemiflora), and Sloanea berteriana are also common.

A study of the effects of radiation on a community requires attention to a large number of species or species groups. Usually the diversity of the biota makes it impossible for any one individual to successfully under-take investigations of all of the constituent species of evident abundance and importance. Consequently a number of specialists have cooperated in the Puerto Rican study (Odum 1964).

Our contribution to the Puerto Rican experiment involves certain of the species of amphibians and reptiles in the forest. Some of these species are conspicuous and obviously abundant. Others are observed infrequently and may indeed be rare. There may be a few species present of which we are unaware. Following a year of continued observations in two 0.7 acre circular plots, we consider the species composition of the areas to be as follows:

Amphibia

Eleutherodactylus portoricensis
E. wightmanae
E. richmondi
E. hedricki
E. eneidae
Leptodactylus albilabris

Reptilia

Typhlops sp.
Alsophis portoricensis

Anolis gundlachi
A. evermanni
A. stratulus
Diploglossus plei
Sphaerodactylus macrolepis
Anolis cuvieri

The tree frogs and lizards are listed in order of apparent abundance, with full recognition of the possible inaccuracies of such a ranking. There is no doubt that Anolis gundlachi, A. evermanni, and Eleutherodactylus portoricensis are abundant--in an absolute sense. E. wightmanae and E. richmondi are also numerous. Other species are rarely encountered and are probably present in low numbers: E. hedricki, Leptodactylus albilabris, A. stratulus, A. cuvieri. The secretive species like Typhlops, Diploglossus and Sphaerodactylus were only captured after cans were buried and used as traps. Their density is unknown. The colubrid snake (Alsophis) is probably as uncommon as its very rare observations indicate. One minor difference between the two areas is suspected: in the upper area E. eneidae seems to be more abundant than E. hedricki.

Whatever the absolute numbers of lizards and tree frogs, and whatever the true relative abundances may be, we believe that these animals--in a functional sense--are the most important vertebrates in the community. There are no native mammals except for bats. Feral mice and rats sustain themselves at varying but low densities. Birds are not numerous. Kahl (1964) estimated about 4 birds per acre in the El Verde forest.

Our efforts have been focused almost exclusively on three species: Anolis gundlachi, A. evermanni, and Eleutherodactylus portoricensis. The form of the data acquired is illustrated by the accompanying machine tabulations. The analyses which follow pertain almost exclusively to Anolis gundlachi, but indicate the questions involved and the technical approach to the data. We designate the lower center as Area 1, the upper center as Area 2. Sex designations are: 1 for males, 2 for females and 3 for undetermined.

What may one expect to occur as a result of the irradiation of the forest? In a precise sense, no one knows. We do have the Brookhaven work and some theoretical considerations on which to base projections. However, there are no clear precedents relating to natural populations of mobile animals. The following effects are deemed reasonable possibilities:

1. acute mortality of individuals
2. prolonged debilitation followed by death or recovery of individuals
3. alteration of the dispersion of the populations
4. changes in vertical stratification of the populations

5. disruption of reproduction and resultant changes in age-or size-distributions of populations
6. changes in mobility of individuals

Accordingly, the following data are keyed to two general objectives: First, to determine whether the two study areas are indeed alike. Can one area legitimately be used as a "control" after the other is irradiated? Second, to develop quantified measures of the make-up and behavior of the assemblages of selected animals in the two area--parameters which can be again evaluated after the irradiation, and which can be used to demostrate effects of the kind enumerated above.

Methods

Preliminary sampling was carried out in July, 1963, but formal initiation of the project did not begin until November, 1963. Observations were largely restricted to the areas between 10 and 30 meters of the centers of the two plots. Areas were examined during alternate weeks. Animals were captured by a number of means, but the most effective proved to be by hand. New animals captured were marked by toe clipping, measured, and released at point of capture. Perch heights were recorded to the nearest 6 inches. Perch diameters less than one inch were recorded as 1/2". Greater diameters were measured and recorded on maps. Sex designations were made when possible. During the spring and summer of 1964 the sampling schedule was modified to include periodic counts of all visible lizards in representative subsections of the two study plots. In June of 1964 two 5 x 5 grids of 25 can traps were installed in each area. The grid interval was 2 meters. These grids were subsequently operated for one day each week. Starting in April, 1964, weekly samples of ovaries of *Anolis gundlachi*, *A. evermanni*, and *Eleutherodactylus portoricensis* were taken. The same three species were collected periodically for the analysis of normal weight-length relationships. Tissue samples (testes, skin, and intestinal epithelium) of the three selected species were preserved and given to Dr. F. K. S. Koo of the Puerto Rico Nuclear Center at Mayaguez.

Field data were transcribed to a special form, from which the data were punched on IBM cards. All background data have now been processed in this manner. Two Fortran programs were written during the summer of 1964 and were used in preliminary data reduction and analysis. Regression analyses and factorial analyses of variance were carried out using programs in the library of the Biostatistics Unit of the UCLA Medical School. The computer used was an IBM 7094. Other less complex analyses were made by mechanical sorting and listing.

Results

1. Density of *Anolis gundlachi*.

Table 1 illustrates a series of density estimates based on capture-recapture analyses of a chain of samples from each of the two areas (Delury 1958).

Sampling was during alternating weeks in each area. The X_t column shows the cumulative number of marked animals at risk in the populations (assuming no mortality). The n_t column shows the size of the samples taken, and the x_t column shows the number of marked animals in each sample. It may be observed that after the fifth sample (at Time 4) the incorporation of further data does not alter the population estimate significantly. In fact, the samples taken at Times 5,6, and 7 are so removed in time from the beginning of the study that the X_t column is no longer valid. This is because the X_t column reflects only the addition of marked animals to the population and makes no allowances for the death of these individuals. Further treatment of these data by other methods is in progress. While it may be assumed that the population estimates of 600+ per o.7 acre are high (because of mortality among marked animals), it is clear that the two areas are remarkably similar.

We believe it useful to develop density estimates by two independent methods. The other technique used was developed by Davis (1942) to estimate densities of forest birds in Cuba. The system involves a complete enumeration of the animals in a representative subsection of the overall area, and an appropriate correction of this count according to the relative sizes of the area censused and the entire area under study.

In the Puerto Rican forest representative areas were selected in the two 30 m circles. The extent of one was about 21% of the entire area under consideration, and that of the other was about 23% of the entire area. Over a period of 4 months three sets of 10 censuses were made in each area. The results of these procedures are shown in Table 2. As may be seen, the numbers of animals observed during each of the three trials were quite similar, and the adjusted estimates of the numbers of individuals in the two 0.7 acre circles are almost identical. However, these estimates are not in accord with those based on capture-recapture analyses.

The disparity is owing primarily to two sources of error. First, the capture-recapture estimates are high, and the reasons for this have already been discussed. We believe that the Davi estimates are low because of an inability to actually enumerate every lizard, even in a small section of forest. In fact, it is likely that at any one time every member of the population is not active and visible. Hence, in the course of any one census the observer registers only a fraction of the entire population. We believe that the actual density of Anolis gundlachi lies between 250 and 650 per 0.7 acre--or between about 350 and 900 per acre. Five hundred per acre is probably a reasonable compromise--and is quite possibly conservative.

This is a remarkable number of lizards. In the desert of southern Nevada 20-30 lizards per acre is "numerous", and some species exist at densities as low as 2 to 10 per acre (Tanner and Jorgensen 1963, Turner 1963, Turner and Gist 1965). However, in more mesic environments higher densities have been recorded (Table 3). In general, numbers are less than 100 per acre but apparently in favorable situations much higher densities may occur. There is some uncertainty as to the size of the population of whiptailed lizards studied by Carpenter along the shore of Lake Texoma. However, in an area 130 feet long and 40 to 50 feet wise (ca. 1/8 acre) Carpenter registered 32 different animals in a oneweek period in July, 1955. The data for Lygosoma lateralis are based on the registeration of 117 different individuals in a one-week period. We believe that the density of Anolis gundlachi observed in the Puerto Rican forest considerably exceeds the usual density of north temperate lizard species.

In terms of the evolution of the tropical forest community, it is interesting to consider how the high densities of Anolis gundlachi have arisen. Possibly the rate of production of the tropical forest is higher than that of north temperate systems. However, we believe it is also important to recognize the existence of a strong vertical component to the activity range of Anolis gundlachi. In general, north temperate lizards occupy a plane. Arboreal species occupy a volume. Davis (1942) made this same point with regard to the Cuban birds. He found that when habitats were compared on an aerial basis, the apparent densities of the same avian species were not similar. However, when habitats were compared in terms of volumes (by taking into account canopy height) conspecific densities were in good accord.

2. Weight-length relationships in Anolis gundlachi

Figure 1 illustrates the regression of body weight on body length in 84 Anolis gundlachi. These data were based on animals collected in the vicinity of (but not within) the study plots. The idea here is that in the irradiated survivors this relationship may be significantly modified (i.e., by loss of weight. Similar weight-length data have been acquired for Anolis evermanni and Eleutherodactylus portoricensis.

3. Growth and size-distributions in Anolis gundlachi populations

Table 4 shows the observed growth in lizards of different sizes. The typical form of such data is one of relatively rapid growth in small animals, followed by a progressive decline in growth rate. The data in Table 4 seem to depart from this pattern, most notably because of the apparent decline in growth rate of animals 44 to 48 mm in length, and the more rapid growth of animals 49 to 64 mm. What is actually illustrated by Table 4 is the cessation of growth in mature females at a snout-vent length of approximately 47 to 48 mm, and the continued growth of males to 60 mm or more in length. The picture is more clearly portrayed in Figure 2, which shows our estimate of growth patterns in male and female Anolis gundlachi. The size dimorphism is much more pronounced than that observed in any American lizards. It is extremely difficult to discriminate between male and female lizards less than 50 mm in length, because both sexes have a dewlap and show no reliable differences in lepidosis or coloration. Hence, most of our designations of female lizards have been based on observed growth rates. Table 4 also indicates the similarity between data obtained in the two study areas.

Figure 3 shows size-distributions based on all animals registered in the two areas between November, 1963, and July, 1964. Approximately the same number of animals was recorded in each area. The size-distributions appear to be reasonably congruent. The peaks above 50 mm represent mature males. The strong peaks at 45 mm reflect mature females plus younger males. Smaller animals are a mixture of both sexes. Because of the difficulty in discriminating between sexes (see above), no attempt has been made to subdivide the size-distributions according to sex.

4. Position of Anolis gundlachi in the forest strata

Rand (1964) has indicated that the "structural habitats" of Puerto Rican anoles may be defined in terms of perch height and perch diameter. According to Rand's observations, A. gundlachi occurs primarily close to the ground (below 5 feet) and on perches of large (3") to moderate (1/2-3") diameter. A. evermanni occurs mainly between 3 and 10 ft above the ground and on perches of diameters exceeding 3". We have made similar observations for these two species in the montane forest.

There were no statistically significant differences between observations made in the two area (Table 5). Hence, data from the two areas were combined in considering the position of the two species in the forest habitat. Table 6 shows the vertical disposition of 2177 captures of Anolis gundlachi and 413 captures of A. evermanni. Table 7 indicates the distribution of capture of the two species according to perch diameter. Captures of lizards on the ground or on rocks are not recorded in Table 7.

Our data are not in particularly good accord with those of Rand (1964). Rand's statement that Anolis evermanni occurs higher in the forest strata than A. gundlachi is not borne out by the numbers set forth in Table 6. However, we believe that this is partly because we recorded only captures. Hence, our records include few animals at heights greater than 8 ft. Our data do not imply a marked difference in the diameters of perches selected by the two species. In both forms, perches of 1 to 3 inches in diameters were used more frequently than those of any other size. Table 7 shows that a somewhat larger proportion of captures of A. evermanni were made on perches exceeding three inches in diameter, but whether this difference is statistically significant is dubious. Rand's observations were made in the forest near La Mina rather than in the El Verde area. Certainly the size-distribution of the trees of the forest will influence the sizes of perches utilized by resident lizards. However, Rand's main point is that the two species show a marked ecological separation, with A. evermanni using perches exceeding 3" in diameter 85% of the time (A. gundlachi 50% of the time). Our figures do not imply this degree of segregation.

We have also inquired as to the possible influence of size on these habitat parameters. The data set forth in Tables 5,6, and 7 probably do not indicate any statistically significant difference between animals greater and less than 50 mm in snout-vent length. This is certainly true of A. evermanni. There is a possibility that small Anolis gundlachi occur on or close to the ground more often than large ones. However, an analysis of the regression of perch height on snout-vent length in Anolis gundlachi showed no significant correlation of these variables (r for Area 1= 0.34, r for Area 2= 0.28).

5. Movements of Anolis gundlachi

An analysis of 480 movements of lizards in the two areas was made. We looked for possible influences due to the size of animals and to the time of year, as well as for differences between the areas. The basic data are shown in Table 8. Table 9 gives the results of a 2x2x3 factorial analysis of variance comparing areas, sizes, and seasons. The analysis shows that the only significant difference in Table 8 is between animals greater and less than 50 mm in snout length. As has been shown earlier, animals greater than 50 mm in snout-vent length are males. Hence, the "size" difference shown in Table 9 may be simply due to a difference between males and females. To test this further it would be necessary to segregate samples of known males and females between the sizes of, say, 40 to 48 mm.

Anolis gundlachi is, in general, a species of low mobility. Even the more vagile adult males occupy localized activity ranges (or territories) in the forest, and movements of more than 12 meters were not often recorded. Longer movements were ordinarily followed by a shift back towards the original point of capture, indicating the habitual use of a prescribed and familiar area. Because of the apparent low mobility of this species, we were usually in doubt as to the reliability of long movements, e.g. of 30 meters or more. Movements of this magnitude were rare and were withheld from the analysis discussed above. However, we believe that occasional movements of this nature do occur (e.g., movements between the two study areas, or to areas beyond 30 meters from the centers of the circles). Data of this form are still being evaluated.

Preliminary inspection of the Anolis evermanni data suggest that this species is more vagile than A. gundlachi.

6. Internal dosimetry

Ideally, the possible influences of the irradiation need to be evaluated in terms of absorbed dose. Free-air doses are to be documented in detail by McCormick. However, it is expected that absorbed doses will be appreciably (and possibly considerably) lower than free-air doses. We hope to estimate the approximate magnitude and variability of absorbed doses in various individuals of the populations by the use of implanted thermoluminescent dosimeters. The dosimeters used were prepared by Edgerton, Germeshausen & Grier, and consisted of a glass cylinder 6.0 mm long and 0.9 mm in diameter containing lithium fluoride powder. Dosimeters recovered after the irradiation will be read by E.G. & G., cleared, and then calibrated against known dosages. The original reading will then be converted to roentgens of absorbed dose. Read-out may range between 1 to 100,000 roentgens. These dosimeters show very little over-response to low-energy gamma radiations (i.e., the response is very close to energy-independent).

Between December 14 and 21, 172 dosimeters were implanted beneath the skin of lizards and tree frogs in the experimental area. Most of the animals so treated were captured and released between 10 and 30 m from the source. However, some were treated between 30 and 45 m. A few animals in the upper area were similarly processed. Dosimeters were inserted subdermally with a No. 17 hypodermic needle. The resulting wound was sealed with collodion. In at least one case the implanting of the dosimeter resulted in the death of the animal. Generally, however, the injection appeared to have no ill effects and on December 19,20, and 21, animals which had previously been processed were observed alive and active in the forest.

The animals processed were as follows:

Anolis gundlachi	101
A. evermanni	32
A. stratulus	6
A. cuvieri	1
Eleutherodactylus portoricensis	29
E. richmondi	2
E. eneidae	1

7. Incidental observations on *Eleutherodactylus hedricki*

This secretive frog was first described by Rivero (1963). Knowledge of the species is based solely on his observations and the description of the type specimen and 7 paratypes, all males or juveniles. During 1964 Gist was able to further observe this little known anuran. The hammering call of the males is distinctive once one is familiar with it. The locations of all calling males were mapped in each of the two areas. Ten males were recorded in the upper center and four in the lower. Males appear to be strongly sedentary. Gist observed a female in the vicinity of a male's hole on June 12. Possibly the females are attracted to the calls of the males, because mating occurs in or near the male's holes and the eggs are deposited there. Amplexus was observed in early June. One clutch of eggs laid on or about June 1 hatched on June 22. The eggs are protected by the male. No eggs were observed unguarded. Eggs were found during June, July, and August, but not during September. On October 20, a clutch of eggs was noted and these eggs hatched on November 3. It is estimated that the time of development in the egg is about 15 to 20 days.

SUMMARY

The repeated sampling of *Anolis gundlachi* in two 0.7 acre areas in the Luquillo Experimental Forest indicates that for every attribute so far evaluated, the populations of the two circles are virtually identical. Hence, one can be legitimately used as a control following the irradiation of the experimental area. Quantified measures of numbers of lizards, weight-lenght relationships, growth, mobility, and other characteristics have been developed, with which may be compared the same parameters following the irradiation.

The density of *Anolis gundlachi* is estimated at between 350 and 900 per acre, with 500 per acre as a conservative best estimate. The equation for regression of body weight (Y) on body length (X) in *Anolis gundlachi* is $Y = .003X^2 - .091X + .305$.

Female *A. gundlachi* attain a size of 47 to 48 mm (snout-vent length) and apparently stop growing. Males may attain 72 to 75 mm is snout-vent length. The sex of most animals less than 50 mm in snout-vent length cannot be ascertained unless subsequent growth records are available. A typical population of *A. gundlachi* shows two peaks in the size-distribution--one at around 65 mm (adult males) and another at 45 to 46 mm (adult females and younger males). The relative abundance of smaller (younger) individuals is

not surely known, because these animals are relatively inconspicuous and are often on the ground where it is difficult to capture them. Both Anolis gundlachi and A. evermanni were captured mainly between about 2 and 5 feet from the ground (means for animals over 50 mm in snout-vent length were 3.88 ft and 3.78 ft. respectively). Depending on the species and the size of individuals, from about 7 to 16% of the animals captured were on the ground. Perches used by the two species were usually 1 to 3 inches in diameter.

Anolis gundlachi is a fairly sedentary species. Average movements were around 6 or 7 m. Animals above 50 mm (all males) were shown to be somewhat more vagile (mean of 240 movements = 7.22 m) than smaller males and females (mean of 240 movements = 6.00 m). Time of year did not influence vagility significantly.

Table 4.

Area	Size range (mm)	N	Total millimeters of growth	Total days of growth	Mean growth (mm/day)
1	30 - 43	38	84	1583	0.053
2		18	38	763	0.050
1	44 - 48	41	37	1999	0.019
2		50	29	2361	0.012
1	49 - 64	40	135	1646	0.082
		42	119	1627	0.073
1	65 +	37	56	1349	0.042
2		36	72	1548	0.046

Growth of Anolis gundlachi in two 0.7 acre areas in the Luquillo Experimental Forest, Puerto Rico. Records were taken between November, 1963 and July, 1964.

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Table 1.

Time	X_t	n_t	x_t	$x_t X_t$	cumulative $x_t X_t$	$n_t X_t^2$	cumulative $n_t X_t^2$	population estimates	95% confidence limits
1	47	73	7	329	-	161257	-	-	-
	79	72	7	553		449352			
2	113	83	13	1469	1798	1059827	1221084	-	-
	144	102	19	2736	3289	2115072	2564424		
3	183	34	8	1464	3262	1138626	2359710	723	392 - 4645*
	227	68	21	4767	8056	3503972	6068396	753	539 - 1252
4	220	62	26	5720	8982	3000800	5360510	597	392 - 1246
	274	57	32	8768	16824	4279332	10347728	615	369 - 1848
5	256	70	24	6144	15126	4587520	9948030	658	496 - 975
	299	26	12	3588	20412	2324426	12672154	621	453 - 984
6	302	49	20	6040	21166	4468996	14417026	681	557 - 876
	313	50	19	5947	26359	4898450	17570604	667	511 - 958
7	331	58	30	9930	31096	6354538	20771564	667	578 - 791
	344	64	32	11008	37367	7573504	25144108	673	555 - 854

* 90% confidence limits

Results of repeated sampling of *Anolis gundlachi* in two 0.7 acre areas in the Luquillo Experimental Forest, Puerto Rico. Samples were taken alternately at two-week intervals between November, 1963 and March, 1964. X_t is the number of marked animals presumably at risk at time of sampling, n_t is the total sample and x_t is the number of marked animals in the sample. Each population estimate is the cumulative $n_t X_t^2$ divided by the cumulative $x_t X_t$. Confidence limits have been calculated as suggested by DeLury (1958).

Table 2.

Area	Total lizards observed; three sets of 10 trials	Ranges	Means	Total area/ area surveyed	Estimated population of 0.7 acre areas	Overall Area means
1	505	41-55	50.5	4.796	242	234
	467	45-50	46.7	"	224	
	489	42-54	48.9	"	235	
2	574	54-65	57.4	4.367	251	247
	575	51-62	57.5	"	251	
	549	53-57	54.9	"	240	

Indirect estimates of abundance of *Anolis gundlachi* in two 0.7 acre areas in the Luquillo Forest, Puerto Rico. Estimates are based on absolute counts of visible individuals in subsections of the two areas.

Table 3. Some density estimates of North American lizards.

Species	Locality	Size of study area (acres)	Individuals recorded (may be approximate)	Estimated density (per acre)	Reference
Sceloporus u. undulatus	Georgia	1.5 0.5	74 56	49* 112*	Crenshaw 1955
Cnemidophorus sexlineatus	Kansas	0.57	23-41	40-72	Fitch 1958
" "	Oklahoma	0.12	50-100	400-800	Carpenter 1959
Sceloporus olivaceus	Texas	10	200	20	Blair 1960
Lygosoma laterale	Louisiana	0.25	117	468*	Turner 1960
Uta stansburiana	Texas	2.07	38 adults 110 juveniles	18 50-56	Tinkle *et al.* 1962

* minimal estimate

Table 5. Mean perch height (ft) and perch diameter (in) of *Anolis gundlachi* and *A. evermanni* of two size-classes from two 0.7-acre areas in the Luquillo Experimental Forest. Captures on the ground are not included. Each cell contains, from top to bottom, the number of observations, the mean, and the variance of the observations.

Species	Snout-vent length-(mm)	Area 1 height	Area 1 diameter	Area 2 height	Area 2 diameter	Areas combined height	Areas combined diameter
	>50	348 3.88 8.60	311 3.32 10.04	383 3.78 8.48	381 3.24 14.27	731 3.83 8.53	692 3.28 12.36
A. gundlachi	50 or less	594 2.23 3.42	505 2.21 7.85	581 2.25 3.99	568 2.22 4.99	1175 2.24 3.70	1073 2.21 6.33
	>50	107 3.78 5.02	107 4.38 23.49	120 3.82 5.38	111 3.20 9.15	227 3.80 4.93	218 3.78 14.62
A. evermanni	50 or less	98 3.44 3.38	97 3.10 7.68	54 3.24 4.54	68 2.75 5.98	152 3.37 3.78	165 2.95 6.97

Table 6. Vertical disposition of 2177 captures of *Anolis gundlachi* and 413 captures of *A. evermanni* in the Luquillo Experimental Forest. Decimal values indicate percent of total captures.

Species	Snout-vent length (mm)	Number of captures	On the ground	Up to 2 ft	2.5-4 ft	4.5-6 ft	6.5-8 ft	>8.0 ft
A. gundlachi	>50	785	6.9	27.0	31.4	18.5	7.9	8.3
	50 or less	1392	15.6	43.9	27.7	9.6	1.9	1.3
A. evermanni	>50	247	8.1	18.2	32.0	31.6	6.5	3.6
	50 or less	166	8.4	20.5	38.6	26.5	4.2	1.8
	all sizes	413	8.2	19.1	34.6	29.6	5.6	2.9

Table 7. Distributions of captures of 1765 *Anolis gundlachi* and 383 *A. evermanni* according to perch diameter in the Luquillo Experimental Forest. Decimal values indicate percent of total captures.

Species	Snout-vent length (mm)	Number of captures	Up to 1 in	1.1 - 3 in	3.1 - 5 in	5.1 - 7 in	>7 in
A. gundlachi	>50	692	19.2	44.1	16.8	9.7	10.2
	50 or less	1073	40.5	34.9	13.9	6.3	4.4
A. evermanni	>50	218	22.9	32.2	19.7	12.4	12.8
	50 or less	165	26.1	37.0	15.7	13.3	7.9
	all sizes	383	24.3	34.2	18.0	12.8	10.7

Table 8. 480 movements of *Anolis gundlachi* in the Luquillo Experimental Forest analyzed according to area, size, and time of year.

	Area 1	Area 2	50 mm or more	Less than 50 mm	November 11- January 15	January 16- March 15	March 16- July 1
N	240	240	240	240	160	160	160
Mean (meters)	6.27	6.95	7.22	6.00	6.19	6.63	7.01

Table 9. Analysis of 480 movements of *Anolis gundlachi* in two 0.7 acre areas in the Luquillo Experimental Forest, Puerto Rico. Factorial analysis of variance shows no differences owing to area or season, but a significant difference between large and small animals.

	Source of variation	Degrees of freedom	Mean squares	F
1.	Area	1	54.015	1.78
2.	Size	1	175.789	5.80*
3.	Season	2	26.687	0.91
4.	1 x 2	1	27.399	0.90
5.	1 x 3	2	7.275	0.24
6.	2 x 3	2	24.961	0.82
7.	1 x 2 x 3	2	44.741	1.47
8.	Within replicates	468	30.328	-

* significant at 3% level

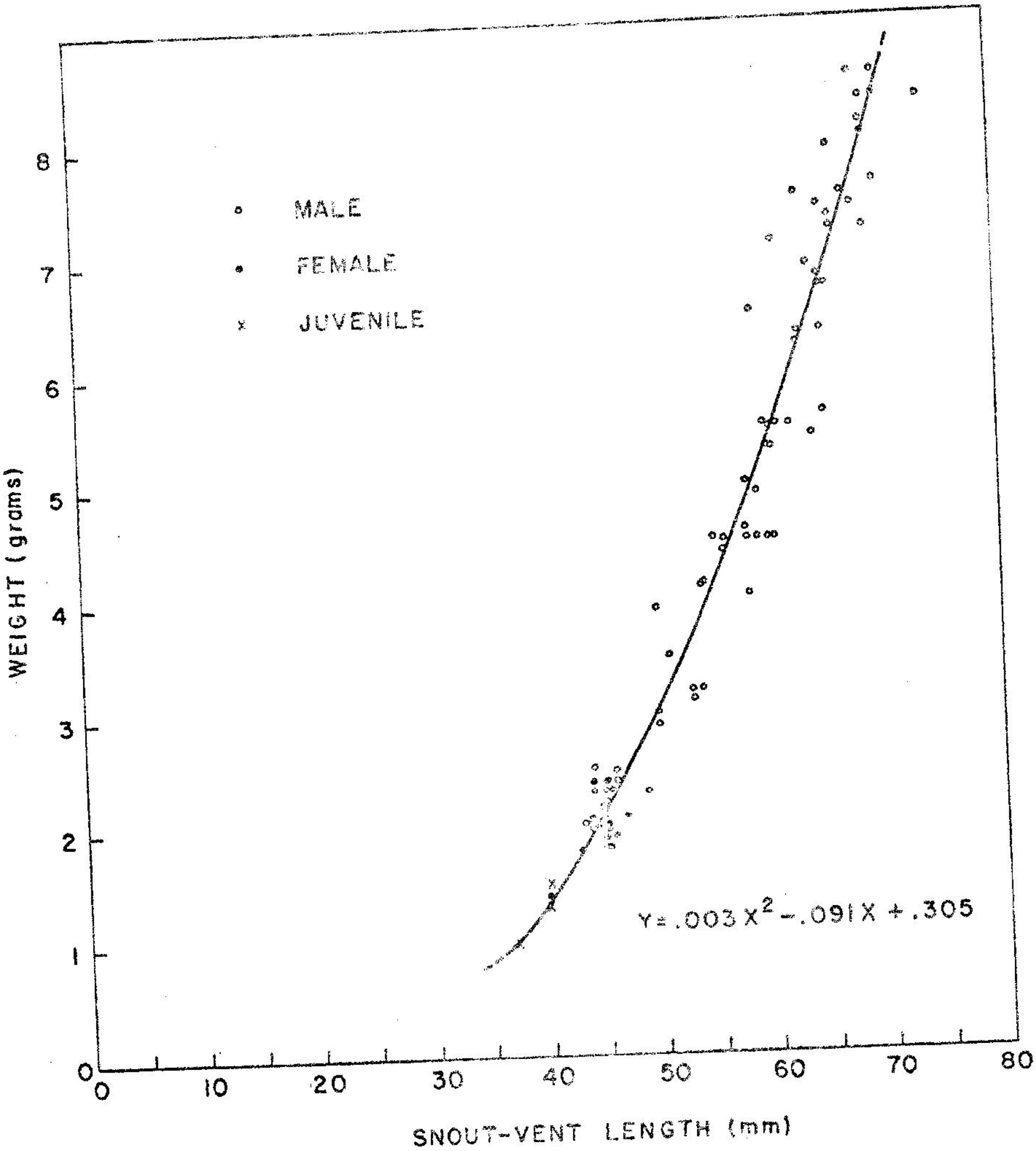

Fig. 1. Relationship of body weight and length in 84 *Anolis gundlachi* from the Luquillo Forest, Puerto Rico.

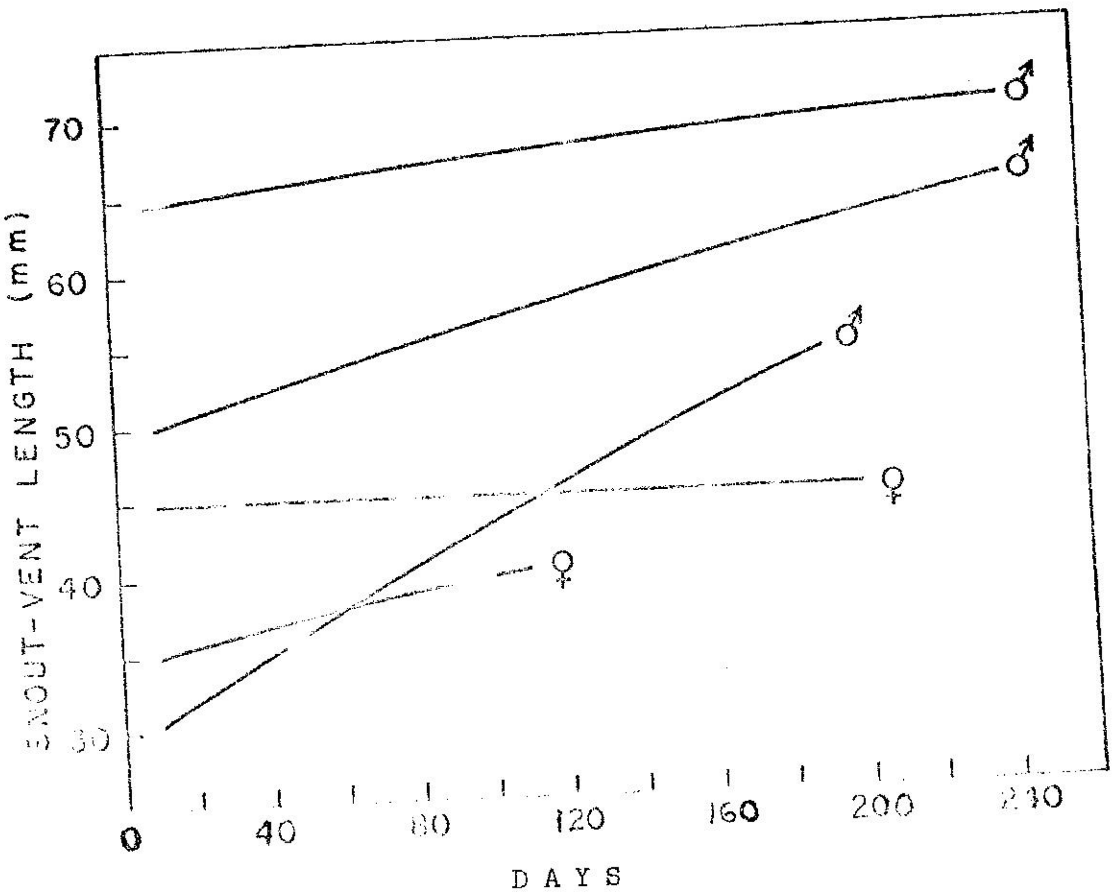

Fig. 2.

Postulated growth rates of male and female <u>Anolis gundlachi</u> in the Luquillo Forest, Puerto Rico.

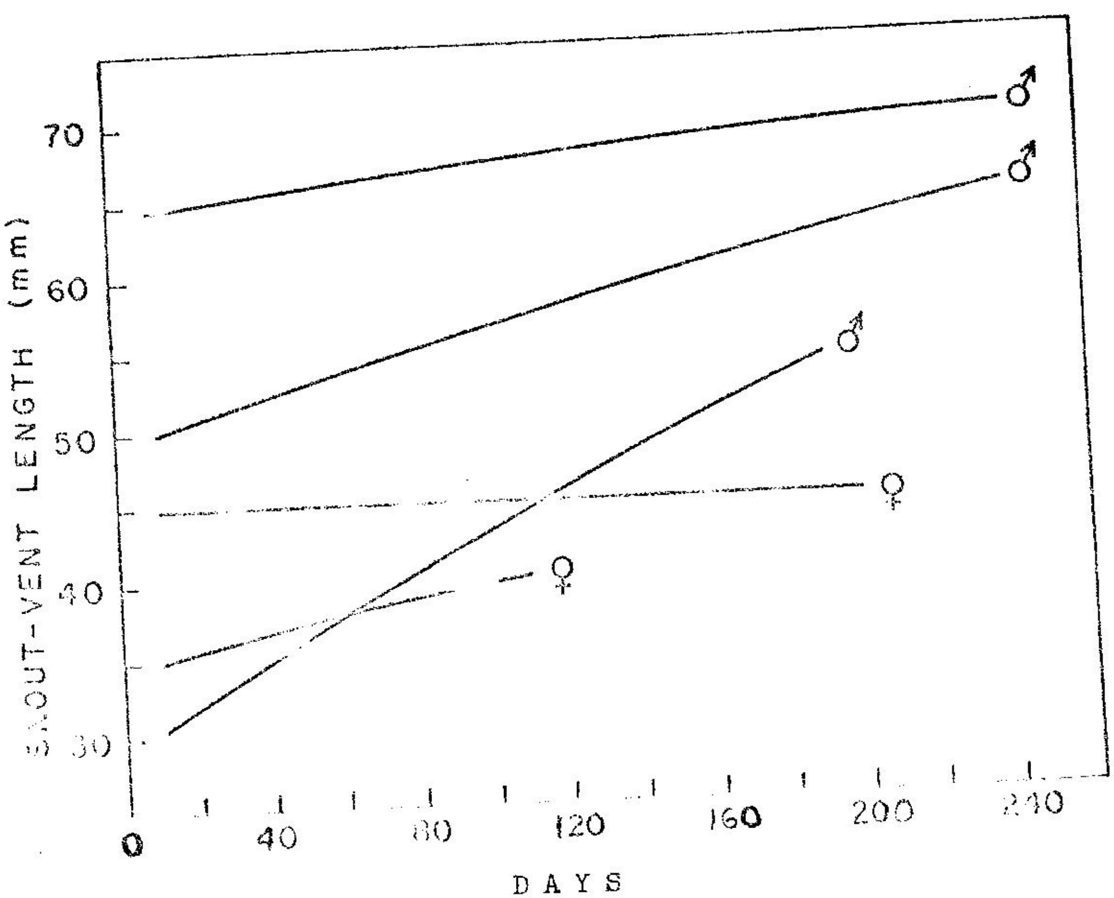

Fig. 2.

Postulated growth rates of male and female <u>Anolis gundlachi</u> in the Luquillo Forest, Puerto Rico.

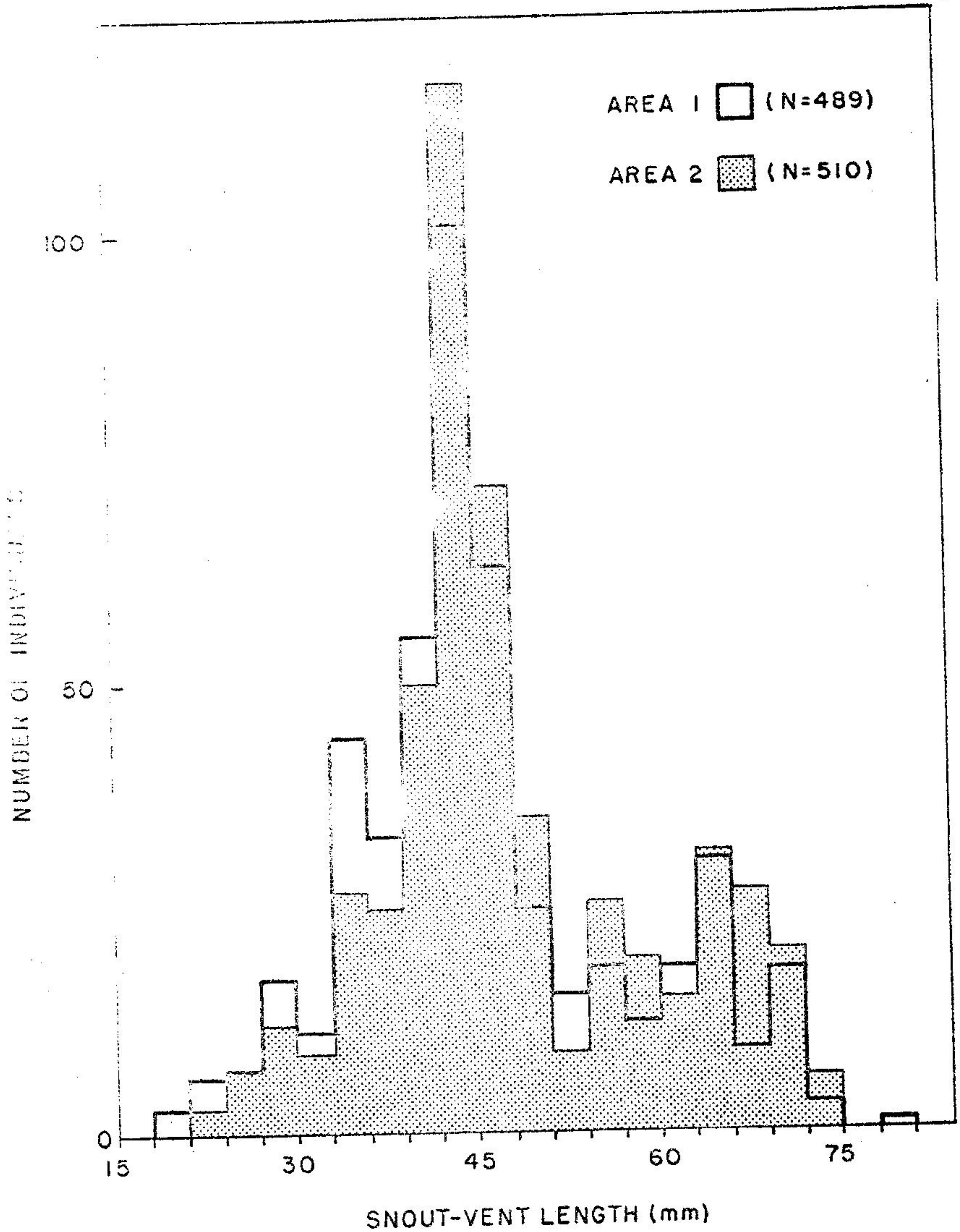

Fig. 31.
Size distributions of Anolis gundlachi registered in two 0.7 acre areas in the Luquillo Forest, Puerto Rico. Data were acquired between November, 1963, and July 1964.

Leaf Fall, Decomposition, and Litter Animals

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Animals

The litter extraction samples are now sorted to broad categories. Summary sheets for given both centers. Although no species separations have yet been made for the mites, I was impressed with the uniformity (or constancy) of the species from different samples. I certainly do not anticipate any difference between the two centers with respect to species present.

As you know, the stratification of the samples was designed to permit detection of radiation effects. Pre-irradiation, there is no reason for regarding the strata as different. I have therefore computed the center mean values in two ways: (1) regarding all 25 samples as a single random sample, and (2) computing a weighted means. Right now of course, method (2) emphasizes the values in the largest strata only and is therefore to be avoided if the supposition that the strata are not different can be justified. Since there is great sampling variability within strata (significant x^2), chi square tests of the mean strata values would be of little value. However, a nonparametric analysis of variance (Kruskal-Wallis) applied to the mite data from each center gave:

Lower center d. f. = 4 $0.80 > p > 0.70$
Upper center d. f. = 4 $0.50 > p > 0.30$

This suggests that the strata do not differ within centers and justifies regarding the total sample as a random sample from the center. When these means are compared:

Upper center 181.7 mites/100 cm^2
Lower center 181.3 mites/100 cm^2

there is little to chose between them. I have not tested any of the other groups because the lower mumbers and numerous blanks create problems. I am not sure in my own mind about the best overall analysis for this study. I intend to consult with out statistician about this matter. But for the present, it appears that the two centers are gratifyingly similar with respect to the density of acarina, and probably with respect to the densities and species decomposition of the other groups of litter fauna.

I have not yet extracted the animals from the clay soil cores. I do not expect to find much except ants and, judged by the litter samples, they have a very spotty distribution.

* Paragraphs extracted from letters, not checked by author.

Litter Samples - El Verde Forest. Stations 1-18, 64/2/9. Stations 19-25, 64/1/28. All values are per 100 cm^2. Lower center.

Station	Acarina (mites)	Chelonethida[1] (Pseudoscorpions)	Collembola	Hymenoptera[2] (ants)	Isoptera (termites)	Other Insects[3]	Myriapoda[4]	Araneida (spiders)	Other Arthropods	Homoptera[5]
W 1	441	-	5	-	-	4	1	1	1-	2
2	134	1	11	1	-	14	3	1	1	13
3	118	-	1	1	-	5	1	-	11	-
4	187	-	2	1	-	3	3	-	4	5
5	112	-	2	5	-	5	4	-	2	2
6	269	2	3	4	-	7	3	1	1	2
7	198	10	13	96	-	9	2	-	1	54
8	90	4	1	9	-	6	9	1	1	7
9	53	2	-	3	-	-	-	-	-	-
10	138	-	-	-	-	8	-	-	6	-
11	404	5	13	-	-	13	5	6	8	-
12	43	4	10	5	-	8	5	1	8	-
13	67	1	13	67	-	8	2	1	1	1
14	175	4	50	-	-	15	39	1	2	5
15	140	1	3	-	-	3	2	1	4	-
16	303	10	32	29	-	7	7	1	1	40
17	249	2	15	1	-	12	18	-	7	7
18	267	4	14	4	-	13	7	1	2	7
19	322	6	21	2	-	58	21	-	-	1
20	38	-	1	56	-	-	-	-	-	3
21	254	2	32	10	-	10	1	3	1	9
22	154	5	12	-	-	14	3	-	6	1
23	143	1	2	2	-	6	1	-	-	2
24	93	1	1	-	-	3	1	-	1	-
25	141	-	1	-	-	3	-	-	1	7
Mean Values										
1-5	198.4	0.2	4.2	1.6	0	6.2	1.4	0.4	3.6	4.4
6-10	149.6	3.6	3.4	22.0	0	6.0	2.8	0.4	1.8	12.6
11-15	165.8	3.0	17.8	14.4	0	9.4	10.6	2.0	3.0	1.2
16-20	235.8	4.4	20.6	18.4	0	18.0	10.6	0.4	2.0	11.6
21-25	157.0	1.8	9.6	2.4	0	7.2	1.2	0.6	1.6	3.8
$\bar{x}$	181.3	2.6	11.1	12.2	0	9.4	5.3	0.8	2.4	6.7
(weighted $\bar{x}$) Center	191.6	3.1	14.4	0	0	11.9	5.9	0.6	1.9	7.6

[1]Probably two species
[2]Most are of one species
[3]Majority are insect larvae and adult Coleoptera
[4]Both Diplopoda and Chilopoda
[5]One species tentatively identified as Coccidae (scale insect)

Litter samples - El Verde Forest. Stations 26-43. Stations 44-50, 64/1/28
All values are per 100 cm^2. Upper Center.

Station	Acarina (mites)	Chelonethida[1] (Pseudoscropions)	Collembola	Hymenoptera[2] (ants)	Isoptera (termites)	Other Insecta[3]	Myriapoda[4]	Araneida (spiders)	Other Arthopods	Homoptera[5]
26	250	3	8	2	-	25	6	2	1	22
27	260	1	15	3	-	16	12	2	5	35
28	193	10	22	5	-	5	4	1	5	77
29	49	2	-	-	-	1	4	-	-	1
30	114	1	3	-	-	9	2	1	1	-
31	456	16	6	-	-	8	4	3	-	20
32	408	15	28	-	-	12	3	-	2	5
33	23	-	-	-	-	2	-	-	-	-
34	128	-	1	-	-	4	-	-	1	-
35	24	-	5	6	-	4	4	-	-	3
36	134	7	33	3	-	21	4	-	2	2
37	66	3	-	7	-	4	-	-	3	-
38	38	-	7	1	-	2	-	1	-	7
39	165	11	8	-	-	2	4	-	-	8
40	57	2	21	-	-	3	3	-	4	1
41	85	3	-	1	-	4	1	-	4	1
42	405	4	77	5	-	6	1	1	-	7
43	141	2	12	1	-	6	4	-	-	5
44	62	-	8	-	-	7	-	-	-	1
45	96	-	5	-	-	1	-	-	2	-
46	215	6	13	141	-	3	8	1	1	5
47	361	3	9	1	5	11	4	-	9	-
48	114	2	2	-	-	3	-	1	2	-
49	533	7	12	80	61	21	10	3	1	6
50	166	8	27	-	-	11	7	-	1	16
Mean Values										
26-30	173.2	3.4	9.6	2.0	0	11.2	5.6	1.2	2.2	27.0
31-35	207.8	6.2	8.0	1.2	0	5.8	2.2	0.6	0.6	5.6
36-40	92.0	4.6	13.8	2.2	0	6.4	2.2	0.2	1.8	3.6
41.45	157.8	1.8	20.4	1.4	0	4.8	1.2	0.2	1.2	2.8
46-50	277.8	5.2	12.6	44.4	13.2	9.8	5.8	1.0	2.8	4.4
x	181.7	4.2	12.9	10.2	2.6	7.6	3.4	0.6	1.7	8.7
Weighted $\bar{X}$ value	208.6	3.7	15.7	19.9	5.7	7.2	3.4	0.6	1.9	3.7

1 Probably two species
2 Most are of one species
3 Majority are insect larvae and adult Coleoptera
4 Both Diplopoda and Chilopoda
5 One species tentatively identified as Coccidae (scale insect)

A biomass estimate is difficult to supply at present. Drying and weighing the samples would destroy their value for later species determinations. I intend to collect additional samples on my next trip and weigh them by species. The present samples are in alcohol and their weights would probably be low. About the best I can do at present is to estimate about one gram or less/m^2. (based on the volume of animals in the sample vials). Of this total, the major portion (75% or more) would consist of myriapoda and insects. The mites, although numerous, weigh very little, but their respiration rate per unit weight will presumably be much higher than that of the larger forms.

Incidentally, the numbers of mites per/m^2 in the rain forests is quite low compared to literature values for temperate forests and my own samples of old fields. I do not yet know if this is due to inefficient extraction. Examination of the leaf litter taken from the extractor will answer this point.

Leaf Fall and Decompostion

Data on the first set of litter bags show an instantaneous rate of disappearance for the Upper Center of 0.35% per day and for the Lower Center only 0.20% per day.

Referring to the annual record of leaf fall, one finds obvious similarity of the two centers with regard to leaf fall. The similarity of the two standing crops of detritus, however, is based on my single sample taken for extraction of arthropods. The mean values were 1350 g/m^2 for the Lower Center and 1290 g/m^2 for the Upper Center. These values include all humus plus inevitably some soil and roots.

Animals extracted from litter samples at the leaf fall stations are given in tables on page 163 and 164. These stations are marked with concrete posts designated W-1, W-2, W-3, etc.

Note: The records of leaf and fruit fall at the 50 stations set out by Dr. Wiegert and continued by the resident staff are given on pp. 34-36. A map of the 50 leaf fall stations which were located with random numbers was given in the 1964 report.

Related data on litter extractions in work prior to 1963 is contained in a manuscript by Odum, Abbott, Selander, Golley, and Wilson. Low numbers in berlese funnels were noted in that work also.

Some data on leaf litter masses are given in this report on page 105.

Third Quarterly Census Report of the Avifauna of the El Verde Experimental Area

by
Harry Recher, University of Pennsylvania

Introduction

The following report is the third in a series on the avifauna of the El Verde experimental area. The data presented here are the result of observations made between 2 December and 8 December, 1964. This is a period of the year which normally marks the beginning of the dry season (Figures I and II). Estimates are given of the bird species density and of territorial or home-range limits of individuals as determined by a series of population censuses.

Data are also presented from a census area located on Mt. Britton, El Yunque National Forest (Figures III and IV). This area differs from the El Verde plot in being at a greater elevation (approximately 850 meters; given as 900 meters in the second report, but now corrected to 850 meters).and receiving a greater amount of precipitation. The forest on this plot has a canopy which seldom exceeds 50 feet and probably averages 35-40 feet. Over 50 per cent of the canopy trees are Sierra Palms (*Euterpe globosa*). According to Bob Smith (personal communication), the forest composition compares to that found on the wetter sites at El Verde.

Observations were made in this area from 9 December through 15 December, 1964.

Included is an annotated checklist of the birds observed on the experimental area.

Procedure

The same census procedure was followed as recorded previously in reports I and II.

A total of six censuses comprising twenty-eight hours of actual census time were made on the El Verde area. The Mt. Britton census was completed in seventeen hours and also involved six separate censuses. An unrecorded number of hours was spent in non-censusing observation.

Results

Territory and Home Range Maps

Figures 5-14 show the recorded territories or positions of the species most frequently recorded during the census period. Maps have been omitted for the Puerto Rican Bullfinch (*Loxigilla portoricensis*). Only one bullfinch was recorded and the vireo is a migrant currently wintering in South America (Bond, 1961). Territorial limits are given for the bananaquit (*Coerba flaveola*) and tody (*Todus mexicanus*) as these two species, only, appeared to be defending territories.

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Reproductive Activity

In general, there was an increase in singing activity (relative to August) among all species present except the bananaquit and ruddy-quail dove (Geotrygon montana). However, vigorous singing with full song was recorded only for the bananaquit, red-necked pigeon (Columba squamosa), bullfinch and Puerto Rican owl (Otus nudipes). Hesitant and weak singing was recorded for the pearly-eyed thrasher (Margarops fuscatus) and the red-legged thrush (Mimocichla plumbea). Stripe- headed tanagers (Spindalis zena) were not recorded singing, but males were frequently heard giving their "sweep" call. "Wing rattling" by todies was recorded three times.

It appears that over-all reproductive activity is now lower than in August, and that most species are just entering the beginning of their reproductive period. April through June would therefore appear to be the peak of the breeding season with several species commencing courtship activities in December and January. Only the bananaquit nests with any regularity throughout the year (Figure 16).

Population Density

As in August, the absence of territorial behavior presented an accurate determination of population density for most species. The figures presented in Table I are therefore subject to more caution than those given for the March-April census. In all probability, the estimates are below the actual number of individuals on the census areas.

Bananaquit

The figure given for the bananaquit represents the number of territorial males. The decrease from March-April through August and December probably reflects a decrease in reproductive activity rather than any decrease in the number of individuals. In addition, numerous immature individuals were observed, but notcounted. There has been a decrease in numbers on both census areas; 9.8% on the El Verde plot and 49.0% on the Mt. Britton plot. The greater decrease at Mt. Britton may reflect the effect of altitude on environmental seasonality and indicates that the El Verde plot is a more stable environment.

Tody

Particular attention was placed on the movements, home range and population density of the tody. As a result, several problems arising during the previous two censuses were resolved. It now appears that the home range of the tody is large relative to its daily movements and that outside of the breeding season, individuals are solitary.

Red-Necked Pigeons and Ruddy Quail Doves

Once again the number of pigeons and doves heard calling during the census were recorded (see Reports I and II). In contrast to the August census, red-necked pigeons were frequently heard calling, though less often than during the March-April period, while ruddy quail doves were heard only infrequently (Table II).

Foraging Groups

Mixed flocks of foraging birds are generally considered characteristic of tropical forests. At El Verde and in the Mt. Britton-El Yunque area, foraging groups are commonly observed. The Puerto Rican Tanager (Neospingus speculiferus) is the most commonly encountered species within these mixed flocks and appears to be the species about which individuals of other species group themselves. Migrant warblers and juvenile bananaquits are also regular components of these mixed flocks. In the March-April period, and especially in August, there were fewer groups noted, and those encountered were smaller in size and contained fewer species than the ones seen in December. The greater number of wintering warblers and the apparent tendency of the Puerto Rican tanager to form larger flocks during December results not only in larger groups, but in a greater number of such groups. In the majority of cases (90%) where a group of foraging Puerto Rican tanagers were observed they were accompanied by bananaquits and warblers. However, occassional groups were also encountered which were comprised only of migrant warblers. During the March-April period and in August, small groups (3-5 individuals) of bananaquits were observed.

The tanagers observed in such flocks tend to bunch together so that all the tanagers in a flock might be found within two or three trees. Warblers and bananaquits tend to be more dispersed with the result that the entire group may trail out thirty or more meters.

In foraging through the forest, these flocks are often joined by individuals of other species (Tody, pearly-eyed thrasher, black-whiskered vireo, bullfinch, bananaquit adults) through whose territories the flock is passing. These birds drop out after a short distance.

Discussion

Seasonal Changes in Population Composition

It now seem well established that there is a pronounced seasonal change in reproductive activity among the birds inhabiting the Luquillo National Forest (Figure 16). Coincident with the reproductive cycle are various changes in population composition. Migration, altitudinal movements and flocking behavior result in pronounced changes in the species composition of the forest as well as affecting local population densities.

The migration of the black-whiskered vireo to South America, the altitudinal movements of the red-necked pigeon and the migration of the North American warblers greatly change the population composition between the fall-winter and spring-summer. A lesser change is effected by the post-reproductive aggregations and flocks of the red-necked pigeon, ruddy-quail dove and Puerto Rican tanager.

Changes in population density accruing through reproduction and mortality appear to be less spectacular. Indeed, it is difficult to detect any changes in population size among resident bird species that cannot be accounted for by sampling error (Table I). This is in contrast to the situation found in temperate climates where non-migrant bird populations fulctuate widely between the post-reproductive peak and the pre-productive low.

The contrast offered by a seasonal change in reporductive activity with the relative stability in population numbers of resident bird species indicated that there is a seasonal fluctuation in available energy, but that the system as a whole is more stable than those found in temperate climates.

The Influx of North American Warblers

The greatest change in population composition results from the migration of North American warblers. Unfortunately, it is impossible at the present time to even estimate the number of warblers occurring as winter residents within the forest. Certainly, it is a considerable number and as such, these birds become an important component of the ecosystem during the winter months. The question must therefore be posed as to whether or not there is a surplus of energy (unoccupied niches) which these birds utilize during their winter residency and which remains unutilized during the summer period while they are absent. In part, the migrations of the black-whiskered vireo accounts for some of these energy differences, but probably the energy utilized by the wintering warblers is greater than that utilized by the breeding vireo population. It is a point which should be more fully resolved. Possibly, the energy demands of the resident bird population are sufficiently lower outside of the breeding season to accomodate the wintering warblers. However, it seems likely that if there was energy available, the resident bird species would continue to breed throughout the year*. Possibly the answer lies with the types of food organisms available and the abilities of the various kinds of birds to utilize them.

* The "ability" of the bananaquit to breed throughout the year may be a result of its utilizing a relatively rich food source (flower nectar, insects attracted to and presumably concentrated at flowers, and perhaps pollen).

Annotated Checklist of the Bird Species Found on or Around the El Verde Experimental Area

Observations are included for species occurring either at the El Verde Station or on El Yunque (including Mt. Britton), but which may not have been recorded for the experimental area proper. Birds not seen on the experimental area are marked with asterisk. Only observations which supplement those recorded in previous reports (I and II) are included.

*Sharpshin Hawk (Accipiter atriatus):

A single individual of this species was observed over the Santurce River below the El Verde experimental area on 5 December. There is supposed to exist a rare Puerto Rican subspecies of this bird which is confined chiefly to the Maricao Forest (Leopold, 1963). Whether the individual reported here was of this subspecies or a vagrant from North America could not be determined.

Red-Tailed Hawk (Buteo jamaicensis):

Individuals of this species were regularly observed soaring over the forested areas at El Verde and El Yunque.

Red-Necked Pigeon (Columba squamosa):

See text pp. 4-6

Ruddy Quail Dove (Geotrygon montana):

See text pp. 4-6

Puerto Rican Parrot (Amazona vittata):

Parrots were seen or heard irregularly on the experimental area throughout the census period. Drewry (personal communication) saw a group of thirteen on the North section and seemed to be most frequent in the area South-East of the South section where they were observed feeding and gathering in an evening roost.

Puerto Rican Lizard Cuckoo (Saurothera vieilloti):

I have yet to observe this bird in the forest even though individuals frequently call close at hand.

Puerto Rican Owl (Otus nudipes):

There appear to be an increase in calling activity over the August period and several individuals were heard calling after sunrise (7:30 a.m.) and before sunset (4:15 p.m.). Two individuals were heard on the El Verde area. In general, this bird is more abundant at lower elevations though it ranges to at least 1,000 meters.

Puerto Rican Emerald Hummingbird (Chlorostilbon maugaeus):

The male previously recorded from the El Yunque Biology Station was still in the area and defending it against other hummingbirds (males only?). Because of the wetter conditions encountered during this trip, fewer hummingbirds than previously were encountered. During wet and cool weather these birds tend to "sit tight".

Puerto Rican Tody (Todus mexicanus):

No burrowing activity was noted, but "wing rattling" was recorded three times. Wing rattling is a sound made by the attenuate outer primaries of both sexes and is heard only during the breeding season (Wetmore, 1927). Territorial defense was noted on one occasion. See text p. 4.

Puerto Rican Woodpecker (Melanerpes portoricensis):

Loggerhead Kingbird (Tyrannus caudifasciatus):

A single individual was recorded twice from the North Section of the El Verde area. I have yet to observe this species in the Mt. Britton-El Yunque area.

Pearly-Eyed Thrasher (Margarops fuscatus):

The raucous calling noted during the August period was heard very infrequently in December, but several individuals were recorded giving very "weak" renditions of their breeding season song.

Individuals were observed feeding on green and ripe fruits of the sierra palm and ripe catkins of the cecropia (Cecropia peltata).

*Red-Legged Thrush (Mimocichla pumbea):

Individuals were heard giveing a very "weak and hesitant" song.

Bananaquit (Coereba flaveola):

Individuals were observed constructing nests on several occasions, but only once was a male and female observed working together.

Territorial males appeared to tolerate juvenile and female bananaquits within their territories. However, the passage of mixed foraging groups containing juvenile bananaquits often excited the male through whose territory the group was passing so that he sang vigorously. It is possible that territories are defended only against other singing males. Certainly these birds forage over a larger area then is indicated by constructing a line about their singing positions. Several males have been observed together in areas where there was a great concentration of food.

Bananaquits sing throughout the day, but there is a pronounced morning and evening chorus (Figure 18). As the scatter of points on the graphs indicates, there is considerable variation throughout the day in the number of songs that are heard at any one time. Singing may be most consistent during the late morning hours (10:00-12:00 a.m.). Each point on the graph may represent the songs of several individuals.

Bananaquits were observed feeding on ripening grapefruits and oranges.

Black-and-White Warbler (Mniotilta varia):

Parula Warbler (Parula americana):

Cape May Warbler (Dendroica tigrina):

A group of eight plus were observed feeding daily in a fruiting and flowering .....(?) tree in the station yard at El Verde. This tree also attracted pearly-eyed thrashers, red-legged thrushes, bullfinches, bananaquits, black-faced grassquits, black-throated blue warblers, black-cowled orioles (Icterus dominicensis) and stripe-headed tanagers. Intraspecific aggression was observed among all species with the exception of the latter four, which occurred either as single individuals or mated pairs. No interspecific aggression was observed.

Cape May warblers were frequently observed hawking insects.

Black-Throated Blue Warbler (Dendroica virens):

The males of this species are perhaps the easiest warblers to see and identify in the forest canopy. Of the fifteen black-throated blues seen, only two were females, but this may be a factor of the greater visibility of the males. As with all the warblers seen (except the waterthrush) these birds restricted their activities to the canopy.

Louisiana Waterthrush (Seiurus motacilla):

Individuals were observed in the Mt. Britton area feeding on insects knocked to the asphalt road by rain. An individual was heard singing.

*American Redstart (Setophaga ruticilla):

Blue-Hooded Euphonia (Tanagra musica):

Reported during November, 1964 by Bob Smith.

Stipe-Headed Tanager (Spindalis zena):

Two contrasting observations were made during this trip on this trip on this species: 1) Males were observed to frequent a particular singing post for at least a week in succession and to call from this perch throughout the day; 2) Males were also observed to fly long distances between singing perches. The possibility is therefore raised that while some individuals are breeding, other are not. At no time was the "warble" song heard.

Males were noted to sing)"seep" song) in flight.

No aggregations of this bird were noted, but on one occasion, individuals of this species were recorded in a mixed foraging flock of Puerto Rican tanagers and warblers.

Puerto Rican Tanager (Neospingus speculifers):

See text pp. 6-7.

The "seep-seep" call which was absent in August was once again heard regularly. In addition, a new series of warble notes was recorded - but not as a song. Wetmore (1927) reports this species as having a pretty warbling song during the breeding seasons (June). The notes heard in December were exchanged between two tanagers following each other about in a bamboo tangle. On one occasion, an individual was observed to pick up a piece of fiber. This was later dropped and left.

Coloration differences which may have represented a sexual dimorphism were particularly obvious.

On 12 December, 1964, tanagers were observed in groups of 2, 2, 2, 2, 1, 8 and 10 (there may have been unseen individuals in all the groups observed).

* Hooded Weaver (Lonchura cucullata):

Observed along road leading to El Verde.

* Black-Faced Grassquit (Tiaris bicolor):

Present, but not singing in the station yard at El Verde.

Puerto Rican Bullfinch (Loxigilla protoricensis):

It is interesting to note that while some males were calling regularly, others known to be in the area were silent or called only infrequently. There is the possibility that a few individuals may be breeding throughout the year.

* Yellow-Faced Grassquit (Tiaris olivacea):

Heard singing in the lowlands, but not along the road near the station turnoff where it has been previously recorded.

Note: For reasons of space, Dr. Recher's first and second reports are not included here although they contain various important data with little overlap with report #3.

Table I

Population Composition (Individuals) of the El Verde and Mt. Britton Census Areas During December, 1964

Species	El Verde (ap. 19 acres) December	Mt. Britton (ap. 8 acres) December
Red-necked Pigeon	N.E.	0.25
Ruddy Quail Dove	15+	0
Puerto Rican Parrot	+	0
Lizard Cuckoo	0.5	+
Puerto Rican Owl	2.0	+
Emerald Hummingbird	2.0	1.0
Tody	20.5	3.0
Puerto Rican Woodpecker	3+	+
Pearly-eyed Thrasher	7.0	2.0
Bananaquit	64.0+ singing males (128.0 individuals)	13.0 singing males (26.0 individuals)
Black-Whiskered Vireo	0	0
Stripe-Headed Tanager	3+ singing males	2.0 singing males
Puerto Rican Tanager	7+	4+
Bullfinch	N.E.	2.0
Loggerhead Kingbird (*Tyrannus dominicensis*)	1 male	0

Table II

Number of Red-Necked Pigeons and Ruddy Quail Doves Calling in the Area Around the El Verde Experimental Plot

	12/2	12/3	12/4	12/5	12/6	12/7	Estimated Population (Pairs)
Red-Necked Pigeon	6	2	5	1	4	4	5
Ruddy Quail Dove	3	0	2	0	0	1	1

Table III

Warblers Observed Between 2 December and 15 December, 1964 at the El Verde and Mt.Britton-El Yunque Areas

Species	El Verde	Mt. Britton	Total
Louisiana Waterthrush (*Seiurus motacilla*)	0	4	4
Black-Throated Blue (*Dendroica caerulescens*)	7	8	15
Redstart (*Setophaga ruticilla*)	0	1	1
Parula (*Parula americana*)	2	4	6
Black-and-White (*Mniotilta varia*)	2	4	6
Cape May (*Dendroica tigrina*)	8	5	13
Unidentified	0	2	2

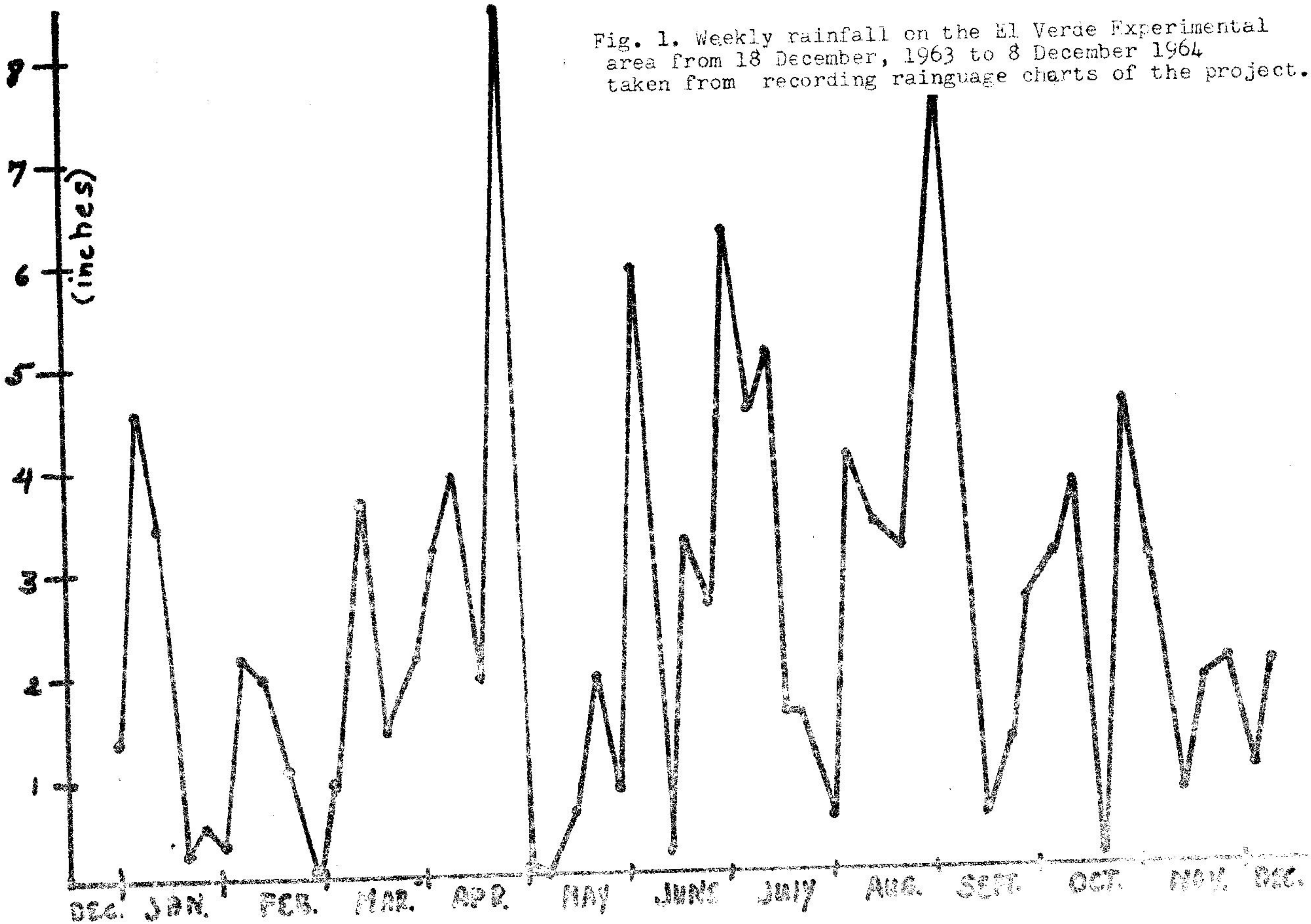


Fig. 1. Weekly rainfall on the El Verde Experimental area from 18 December, 1963 to 8 December 1964 taken from recording rainguage charts of the project.

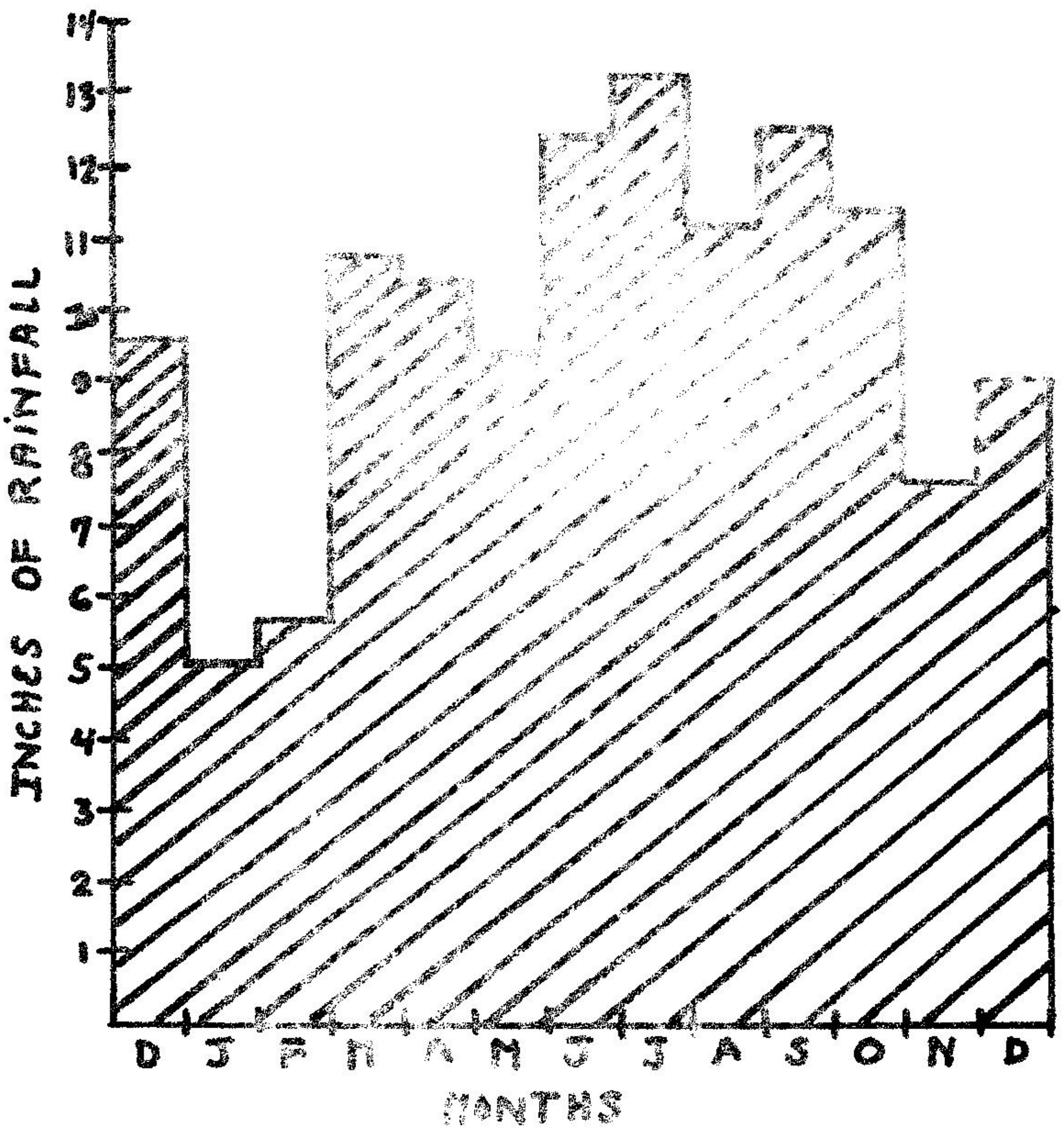


Fig. 11. Monthly rainfall on the El Verde Experimental Area from 18 December, 1963 to [illegible] December, 1964 from recording rain guage of the project.

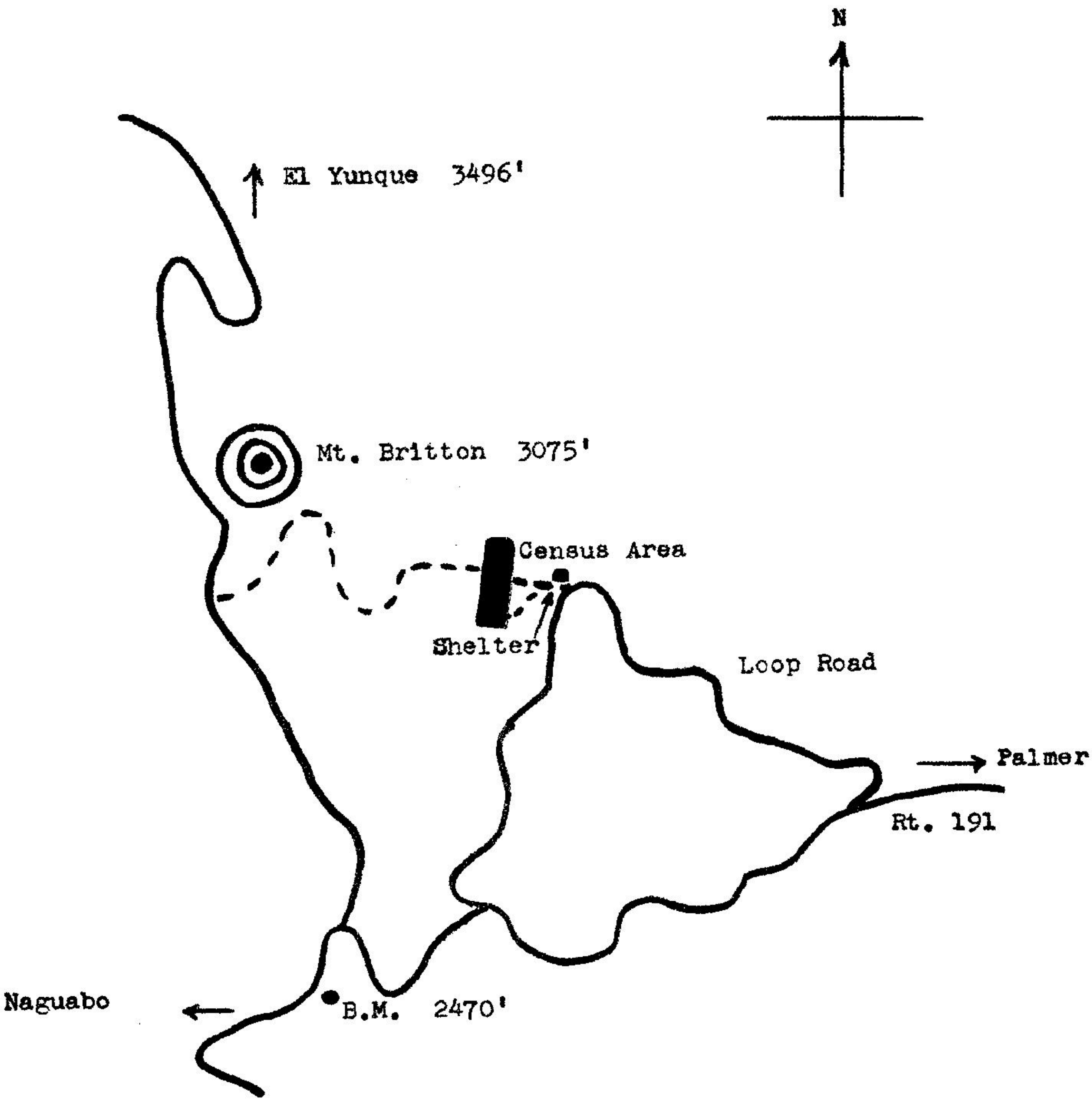
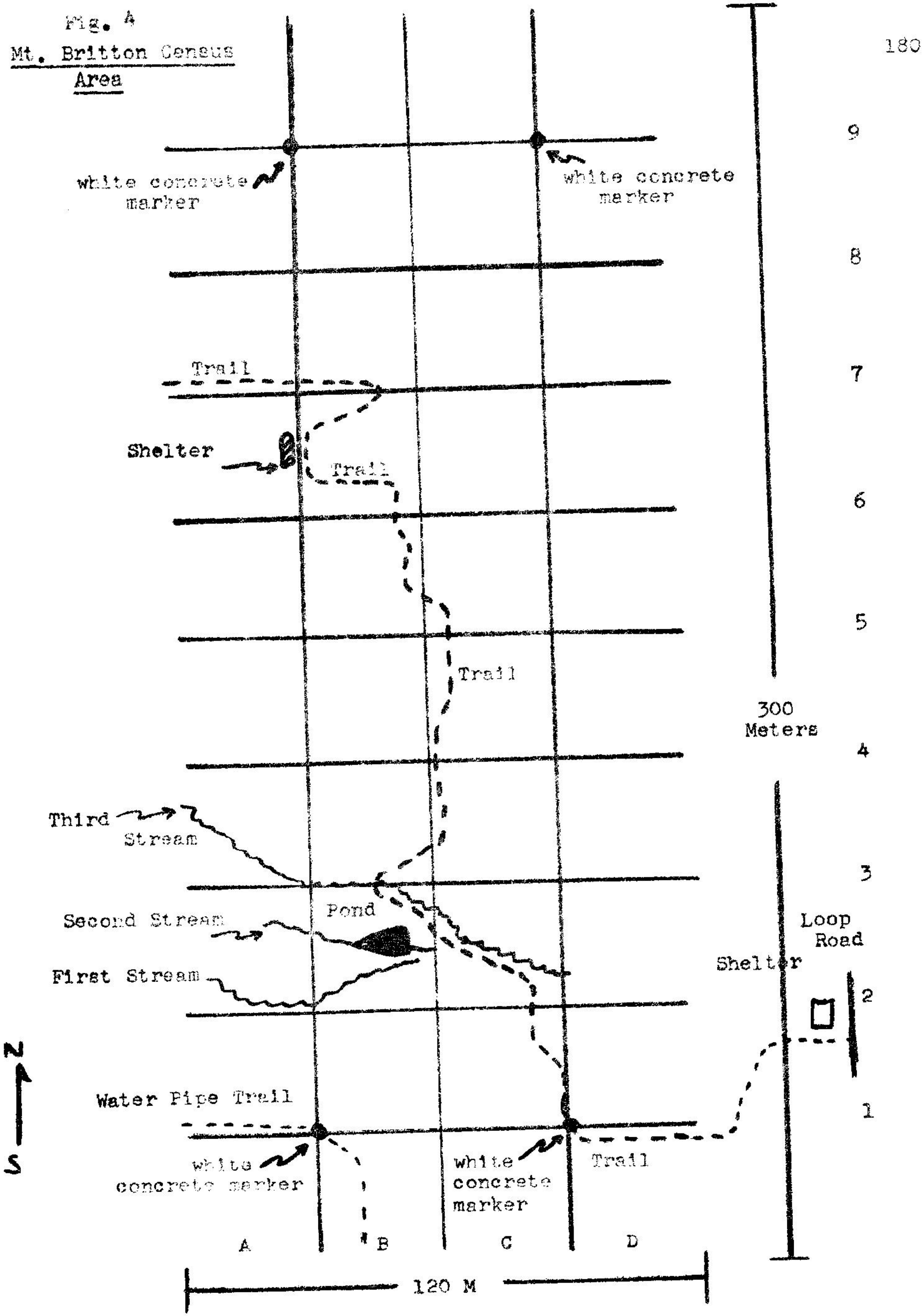
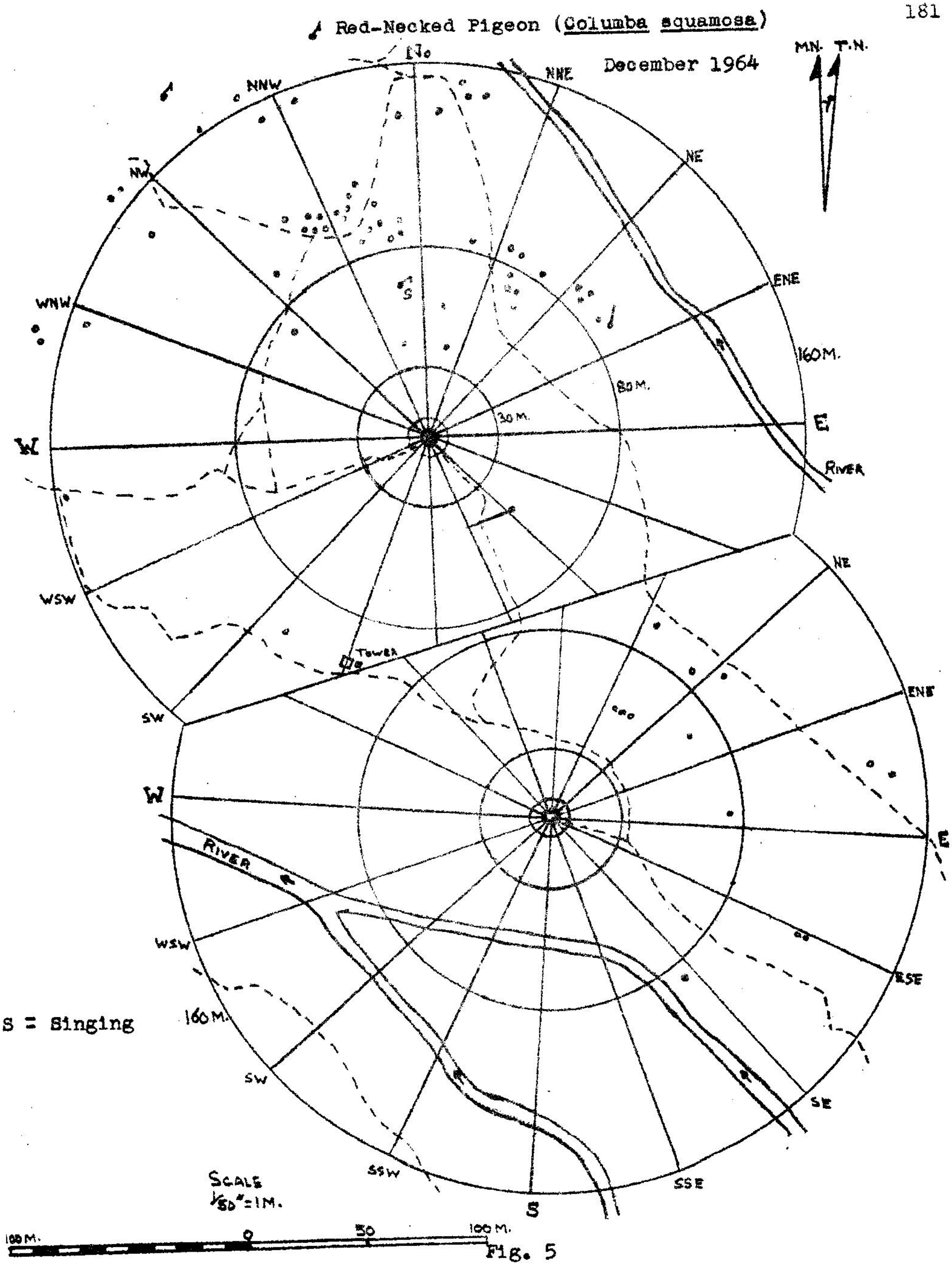


Fig. 3

Location of Mt. Britton Census Area

Fig. A
Mt. Britton Census Area





S = Singing

Fig. 5

Ruddy Quail Dove (Geotrygon montana)

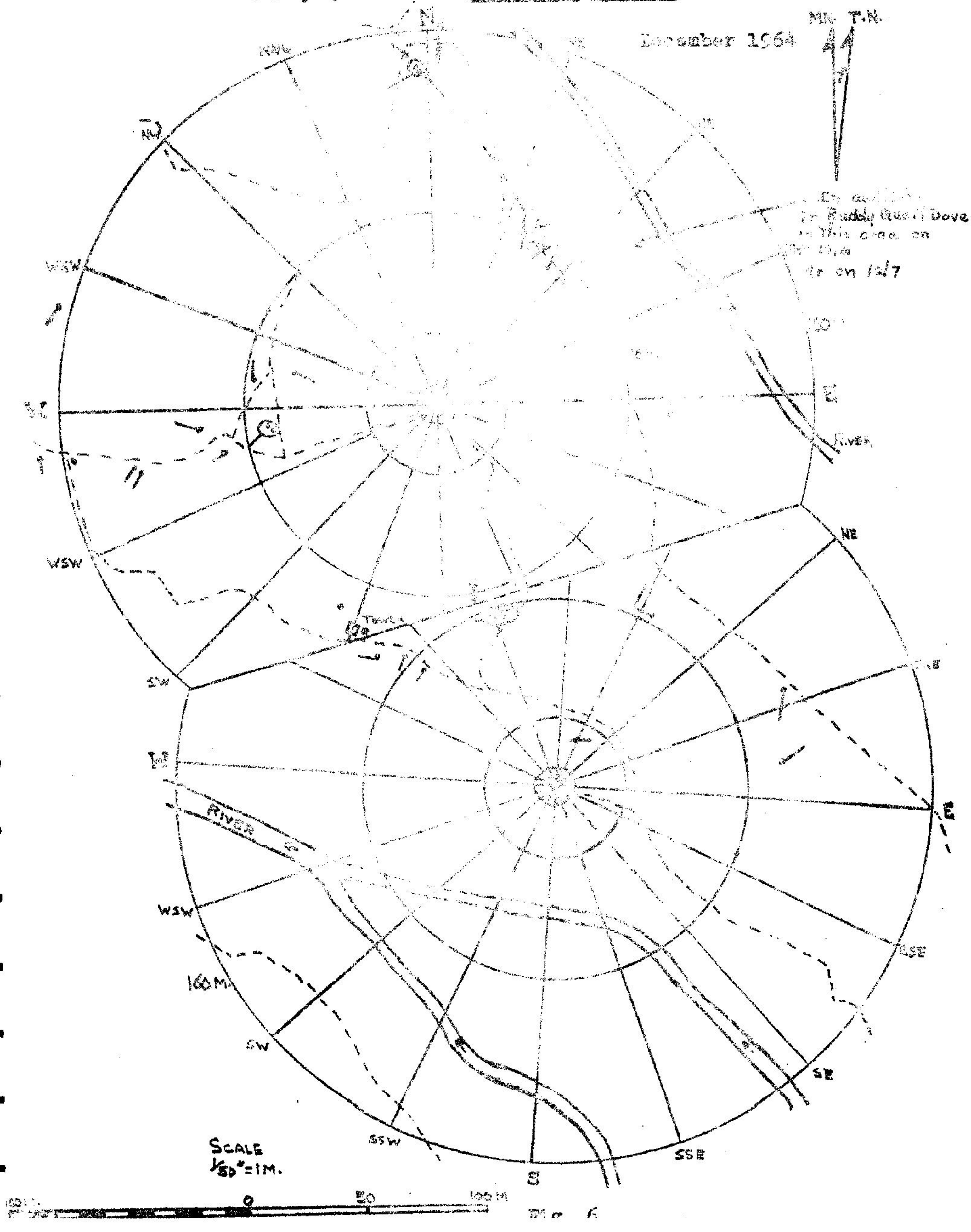


Fig. 6

Puerto Rican Lizard Cuckoo (<u>Saurothera</u> <u>vieilloti</u>)

December 1964

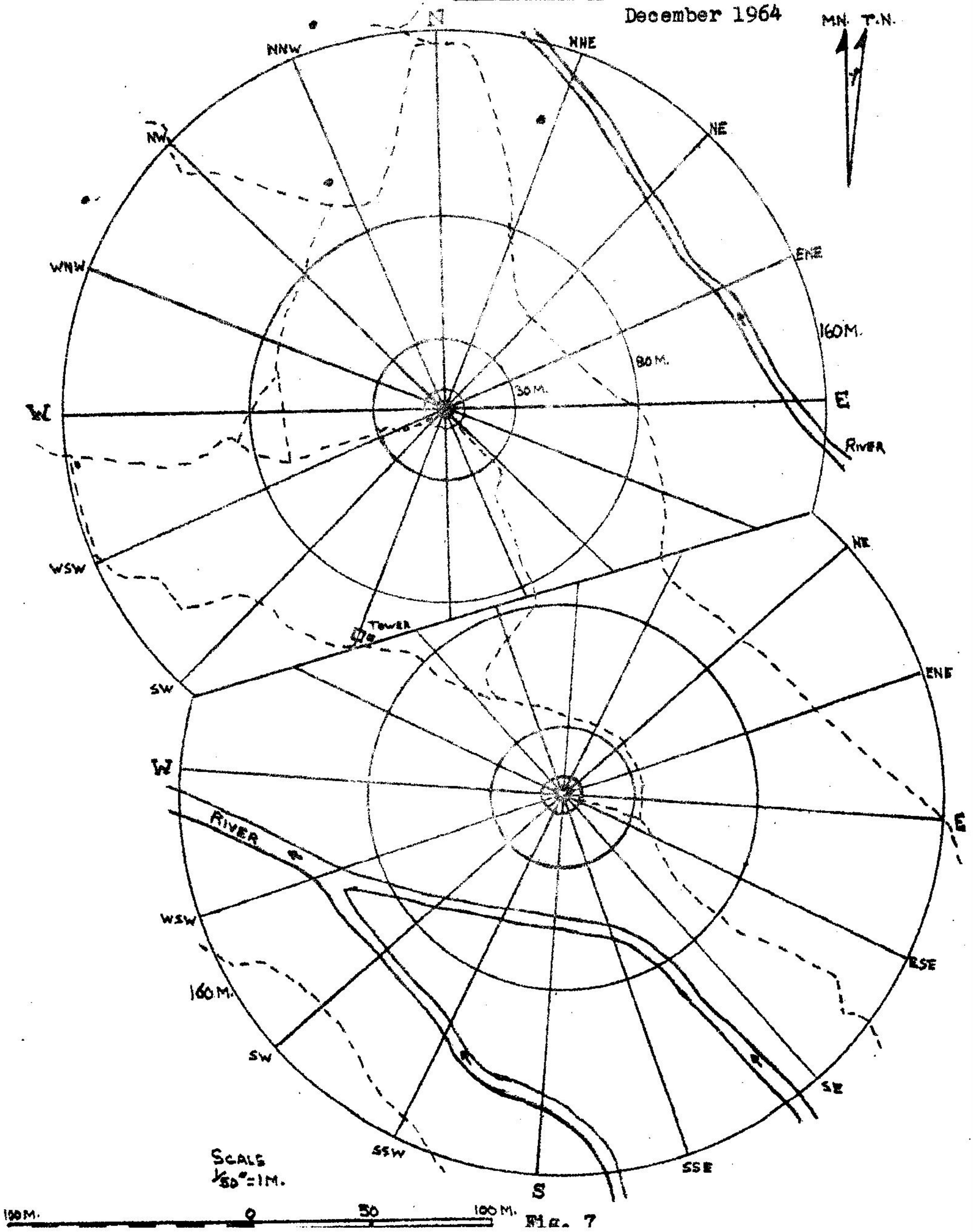


Fig. 7

Puerto Rican Emerald Hummingbird (Chlorostilbon maugaeus)

December 1964

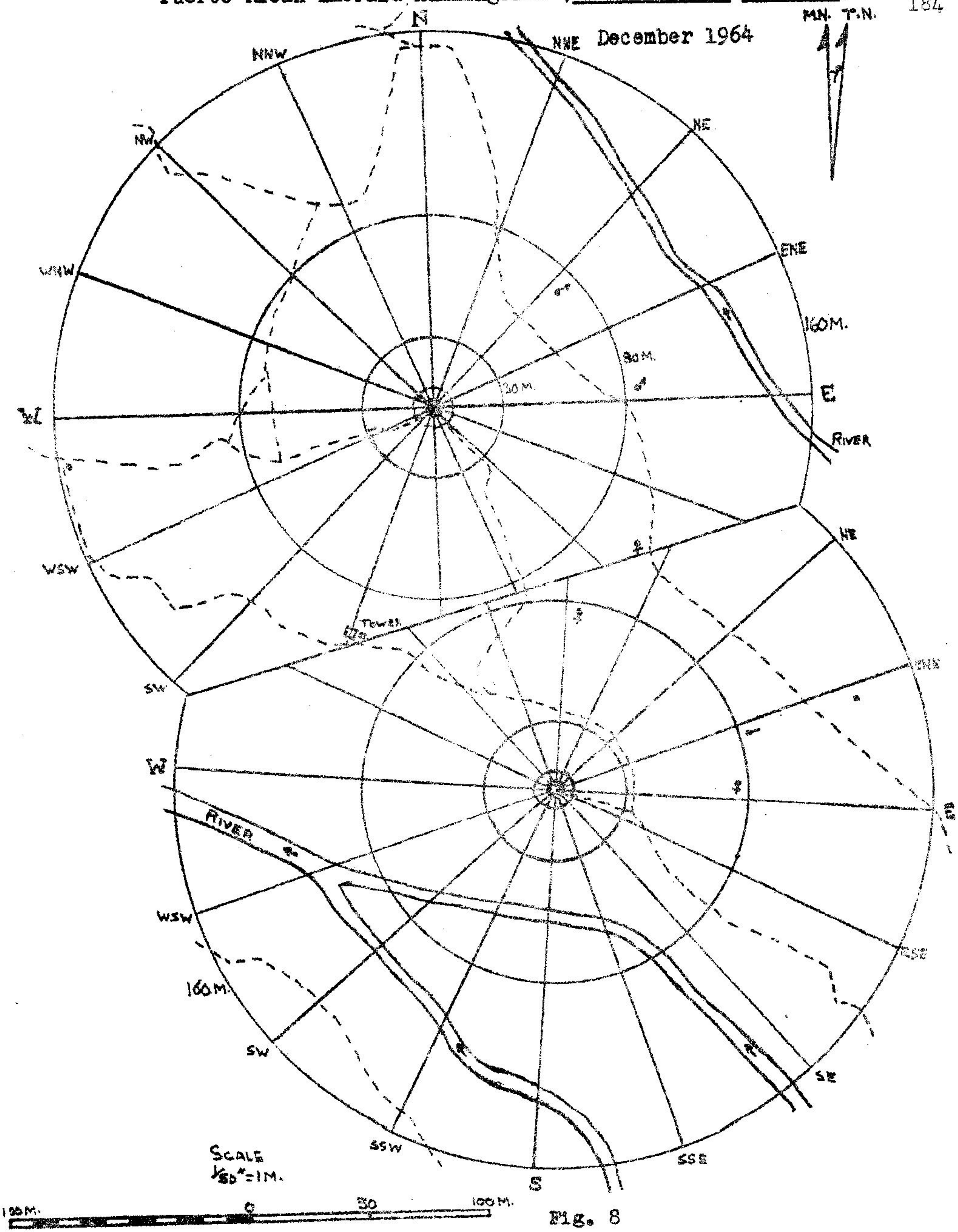


Fig. 8

Puerto Rican Tody (Todus mexicanus)

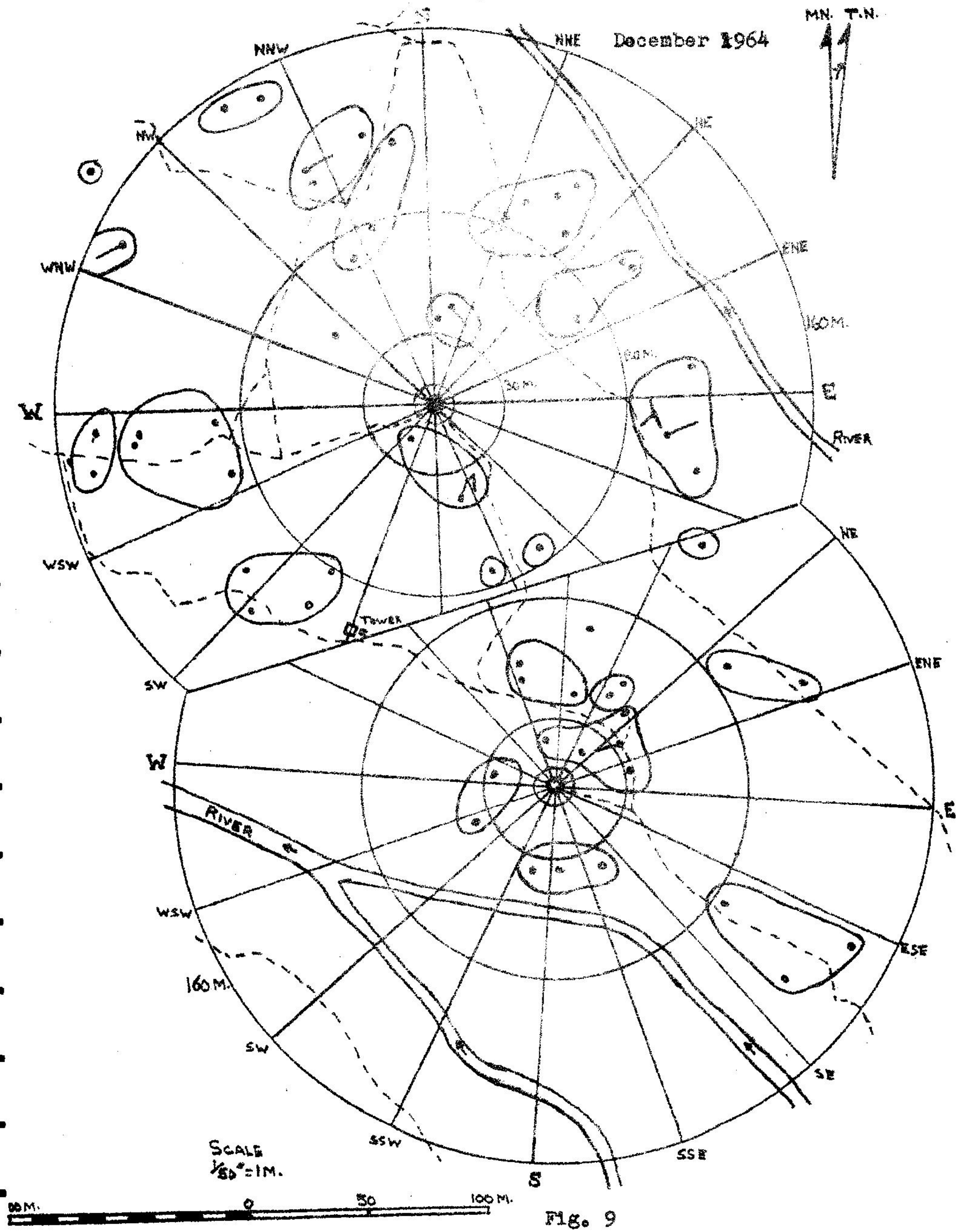


Fig. 9

December 1964

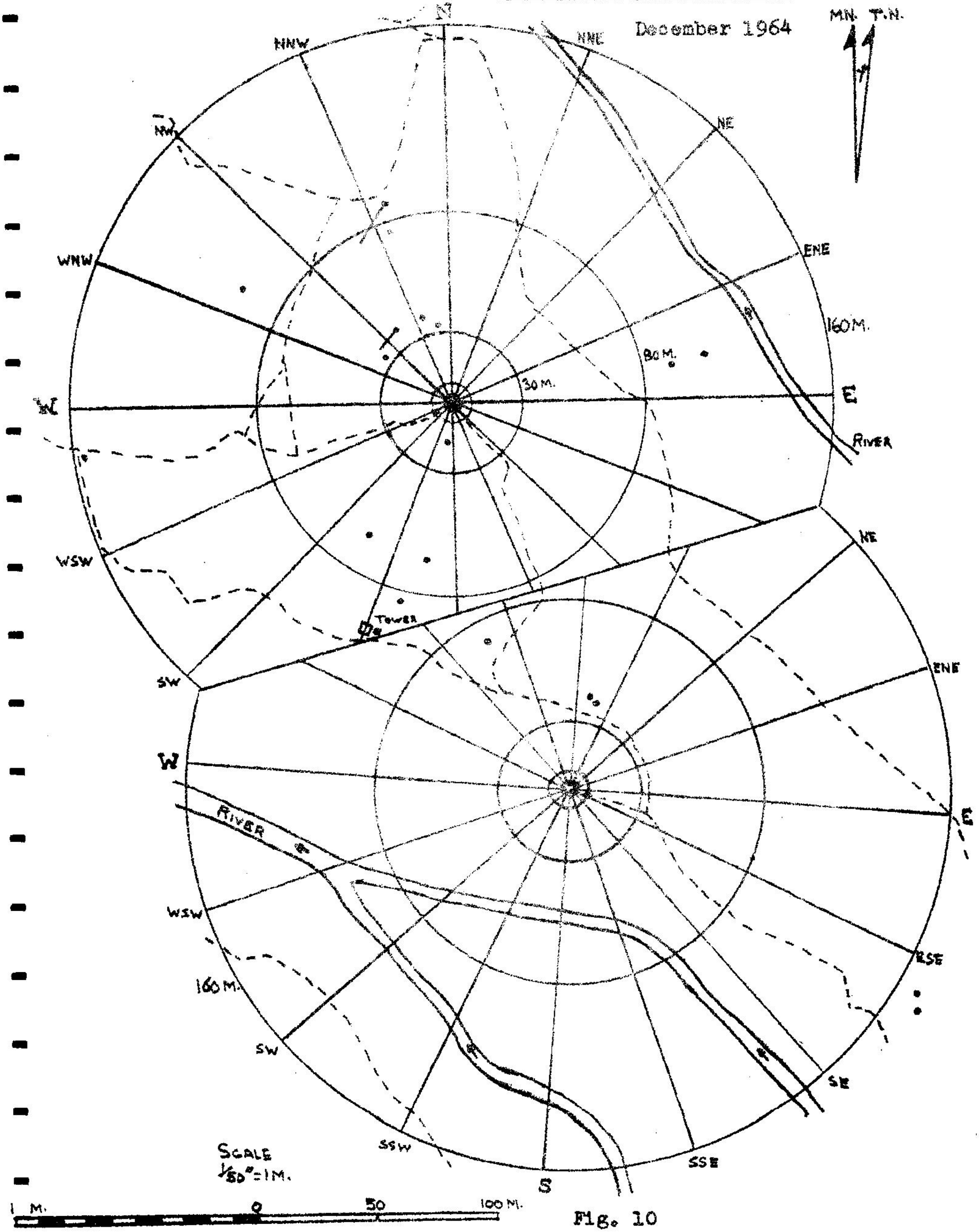
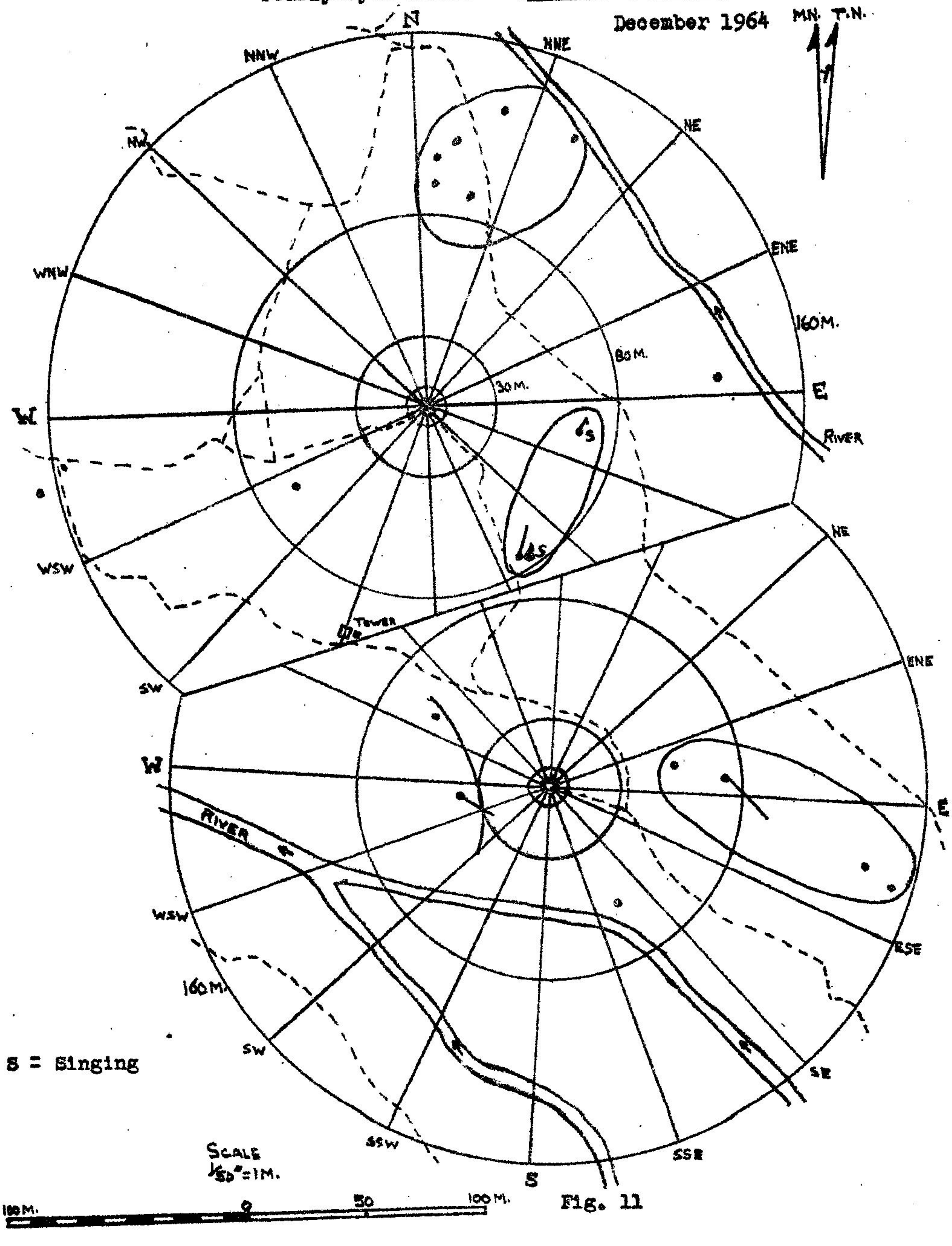


Fig. 10

Pearly-Eyed Thrasher (Margarops fuscatus)

December 1964



S = Singing

Fig. 11

Bananaquit (Coereba flaveola)

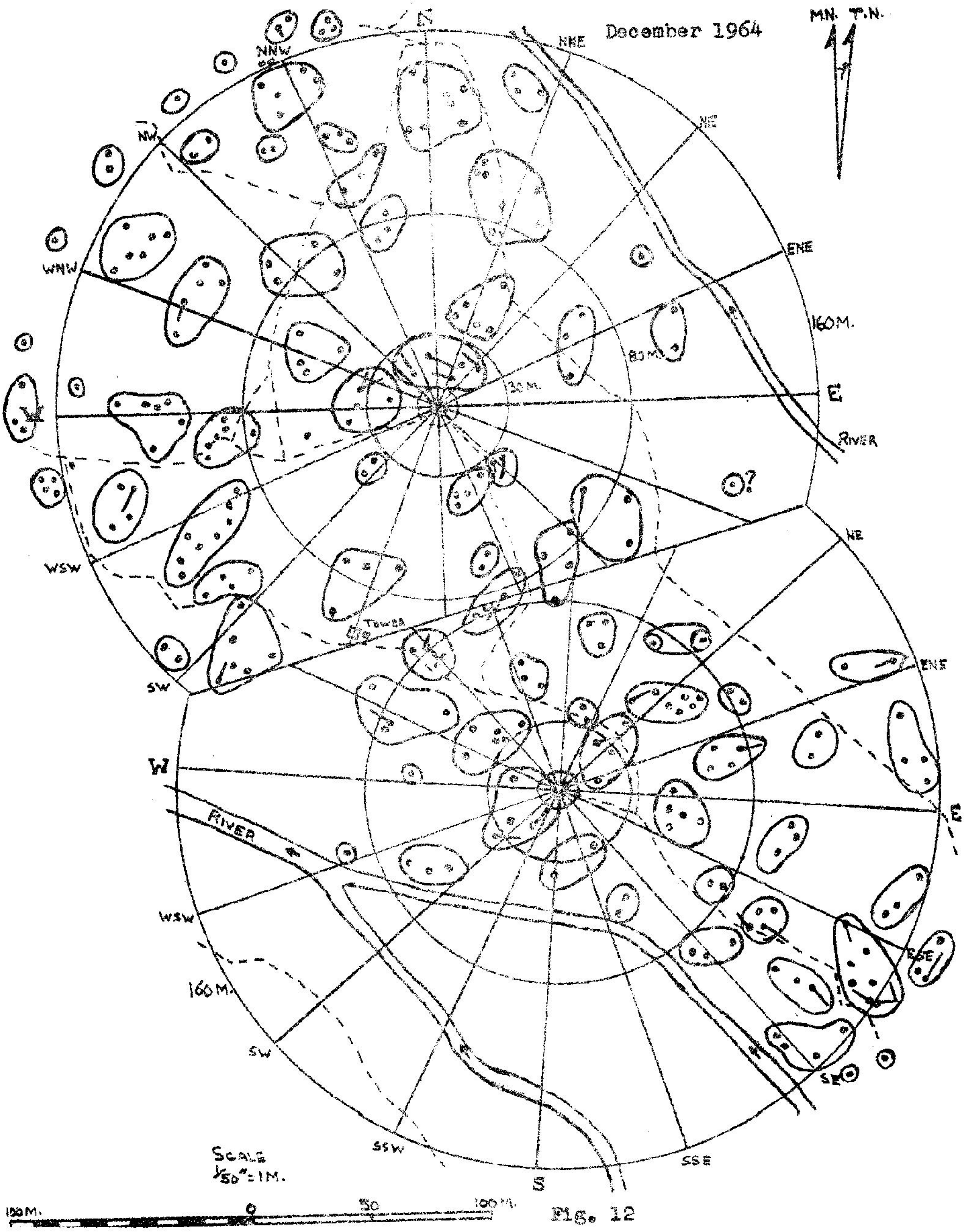


Fig. 12

Stripe-Headed Tanager (Spindalis zena)

December 1964

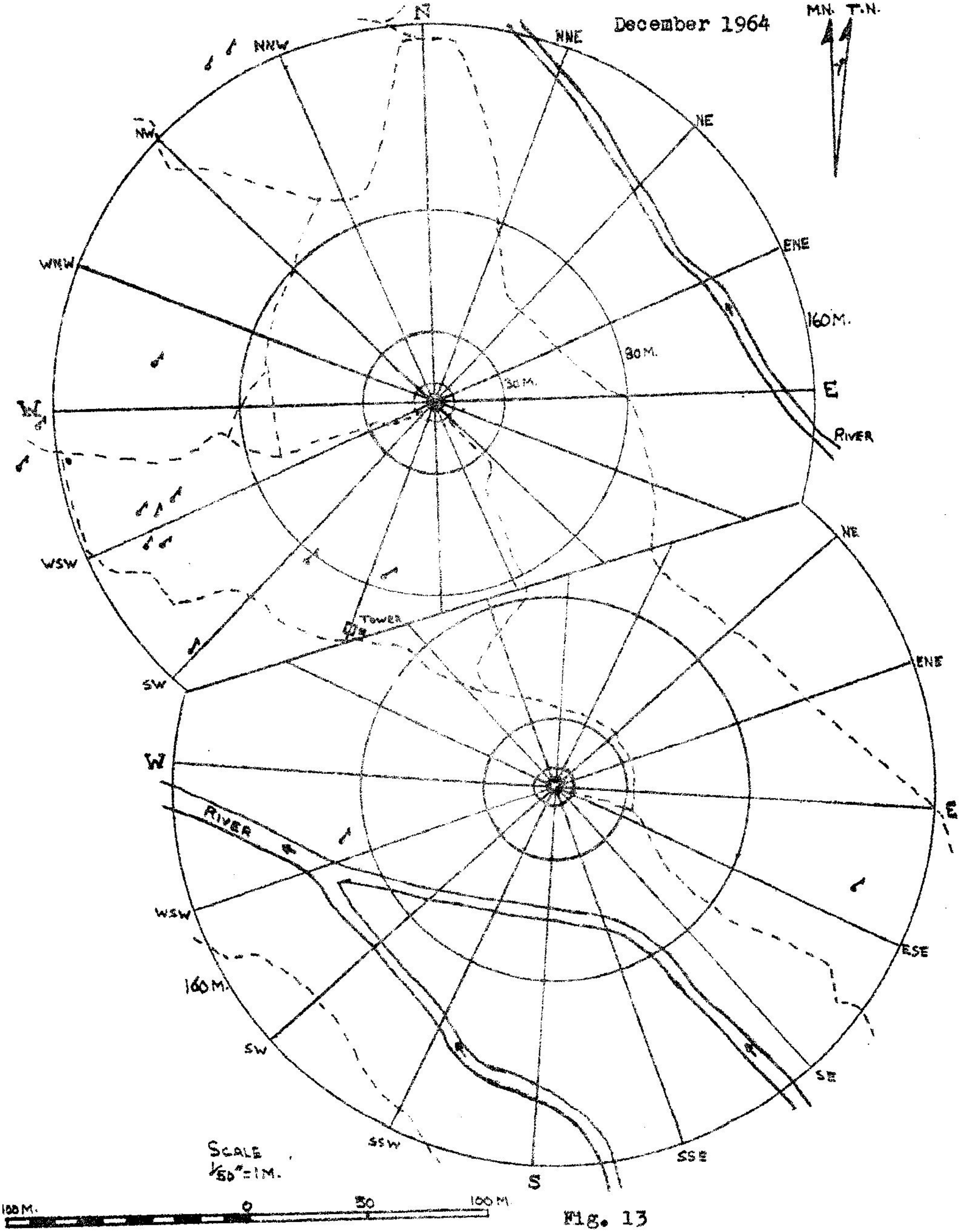


Fig. 13

Puerto Rican Tanager (*Neospingus speculiferus*)

December 1964

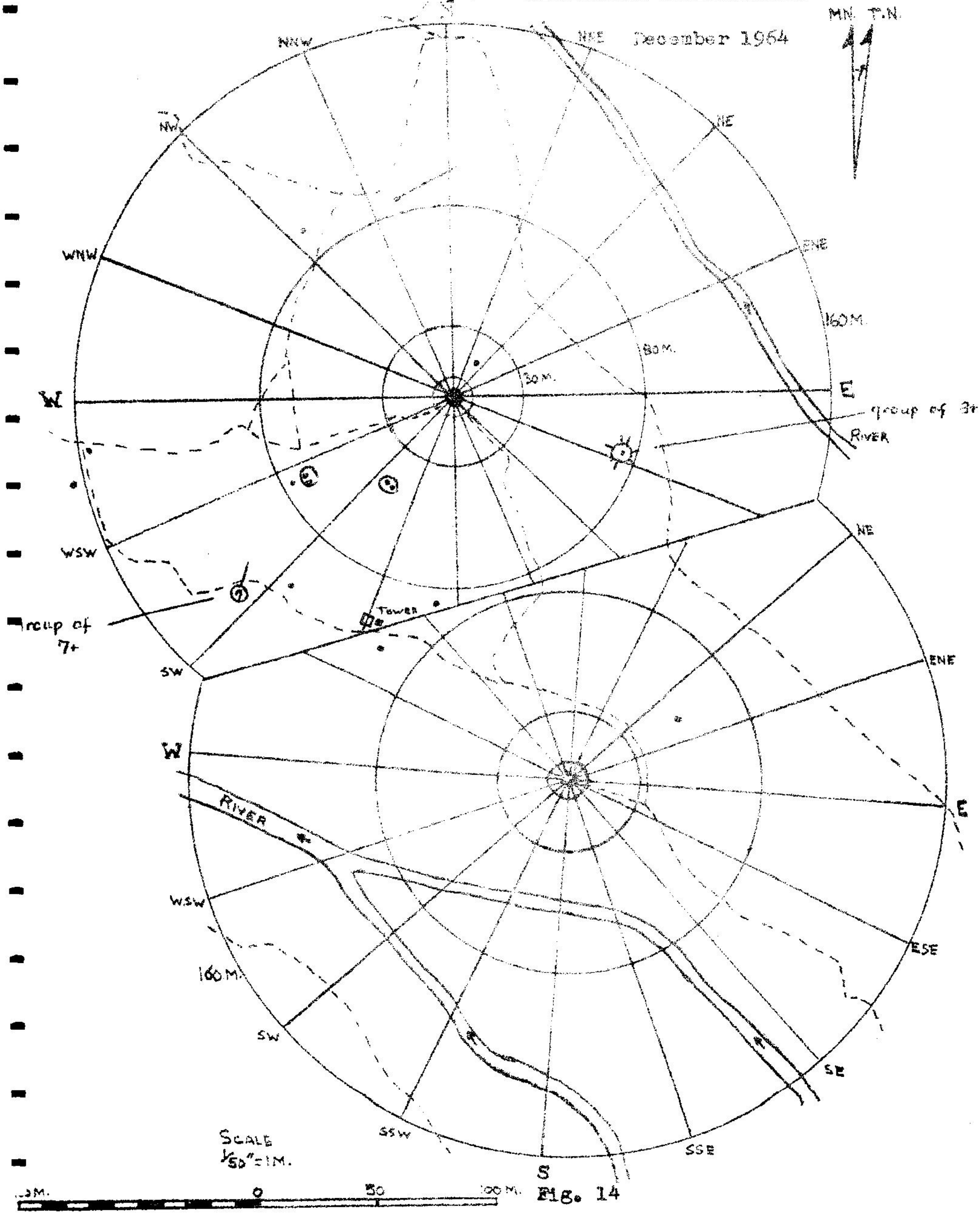
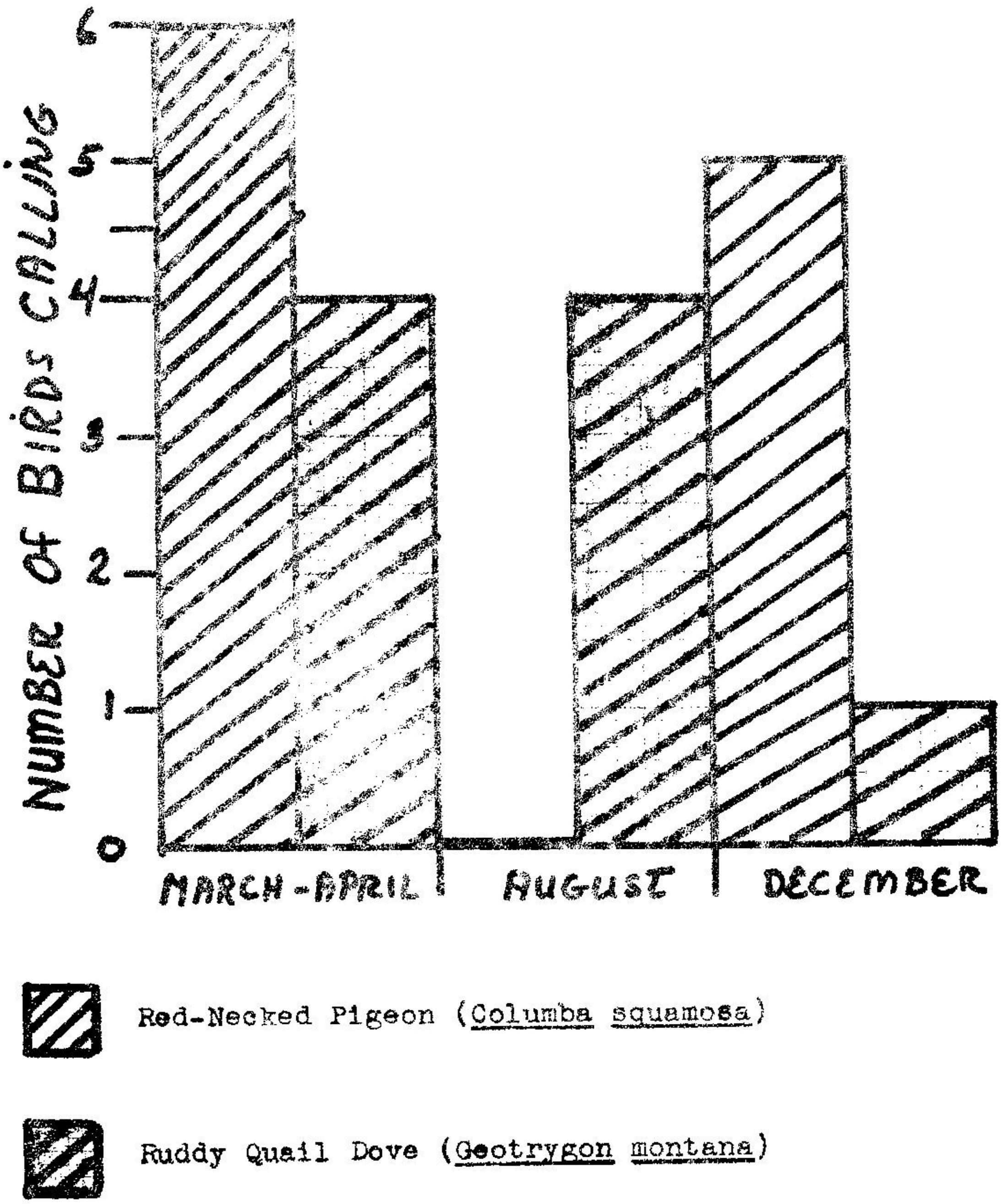


Fig. 14

Relative Number of Red-Necked Pigeons and Ruddy Quail Doves Calling During the March-April, August and December Census Periods



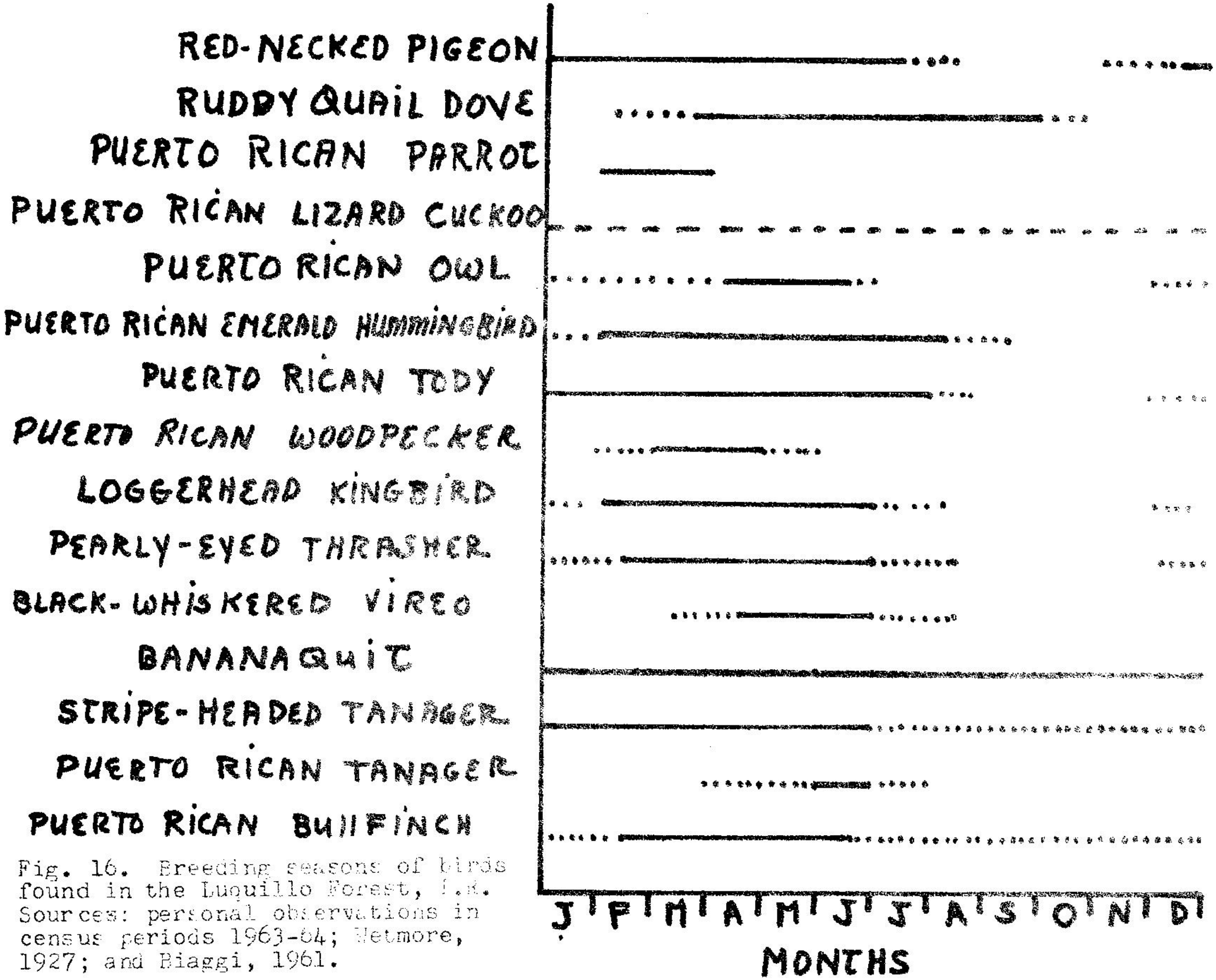
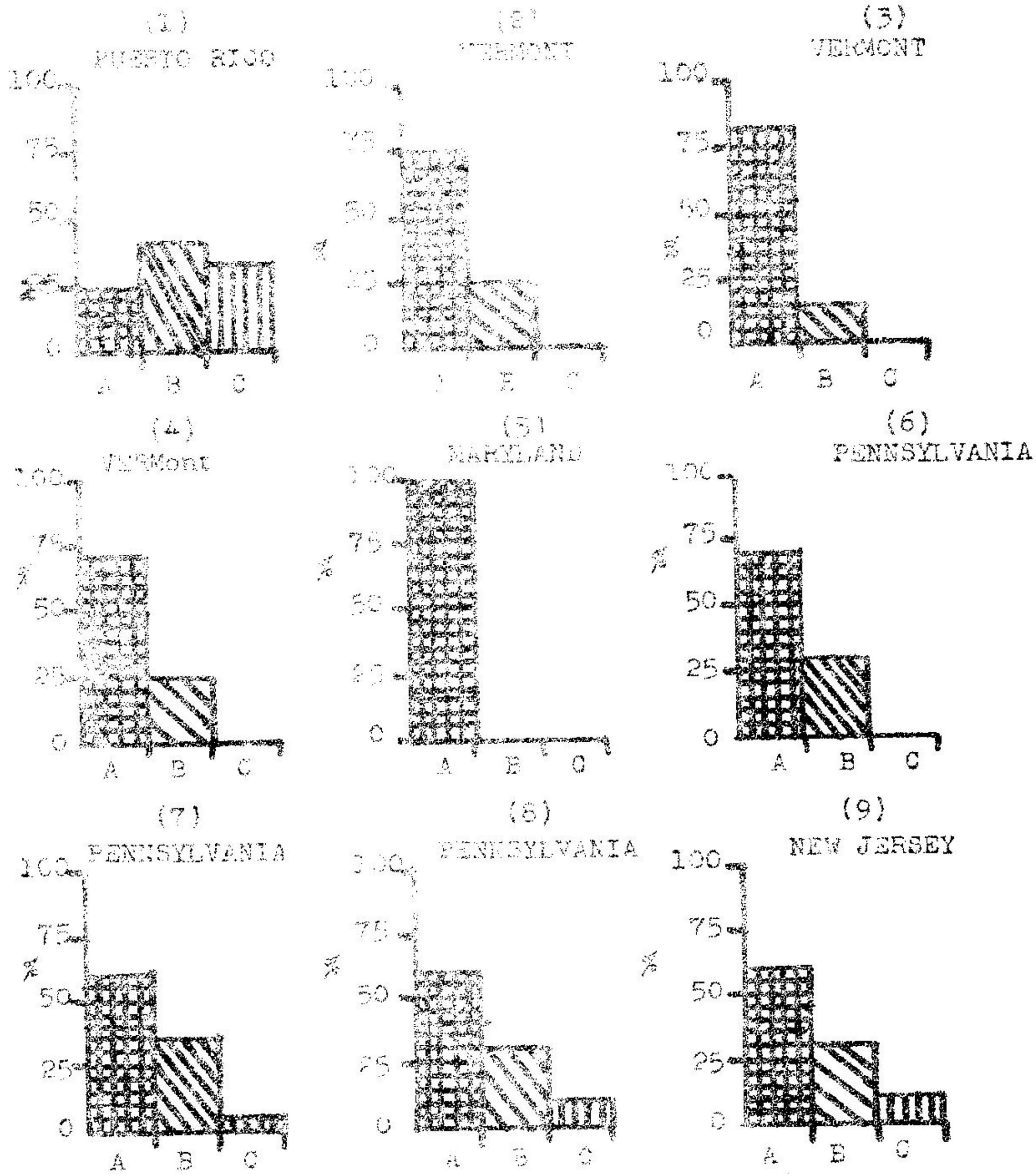


Fig. 16. Breeding seasons of birds found in the Luquillo Forest, P.R. Sources: personal observations in census periods 1963-64; Wetmore, 1927; and Biaggi, 1961.



A = Insectivorous Birds

B = Omnivorous Birds

C = Frugivorous Birds

[illegible] 17. Relative [illegible] of insectivorous, [illegible] frugivorous [illegible] birds [illegible] Puerto Rico and [illegible] communities of [illegible] North America [illegible] (1 -18) [illegible]

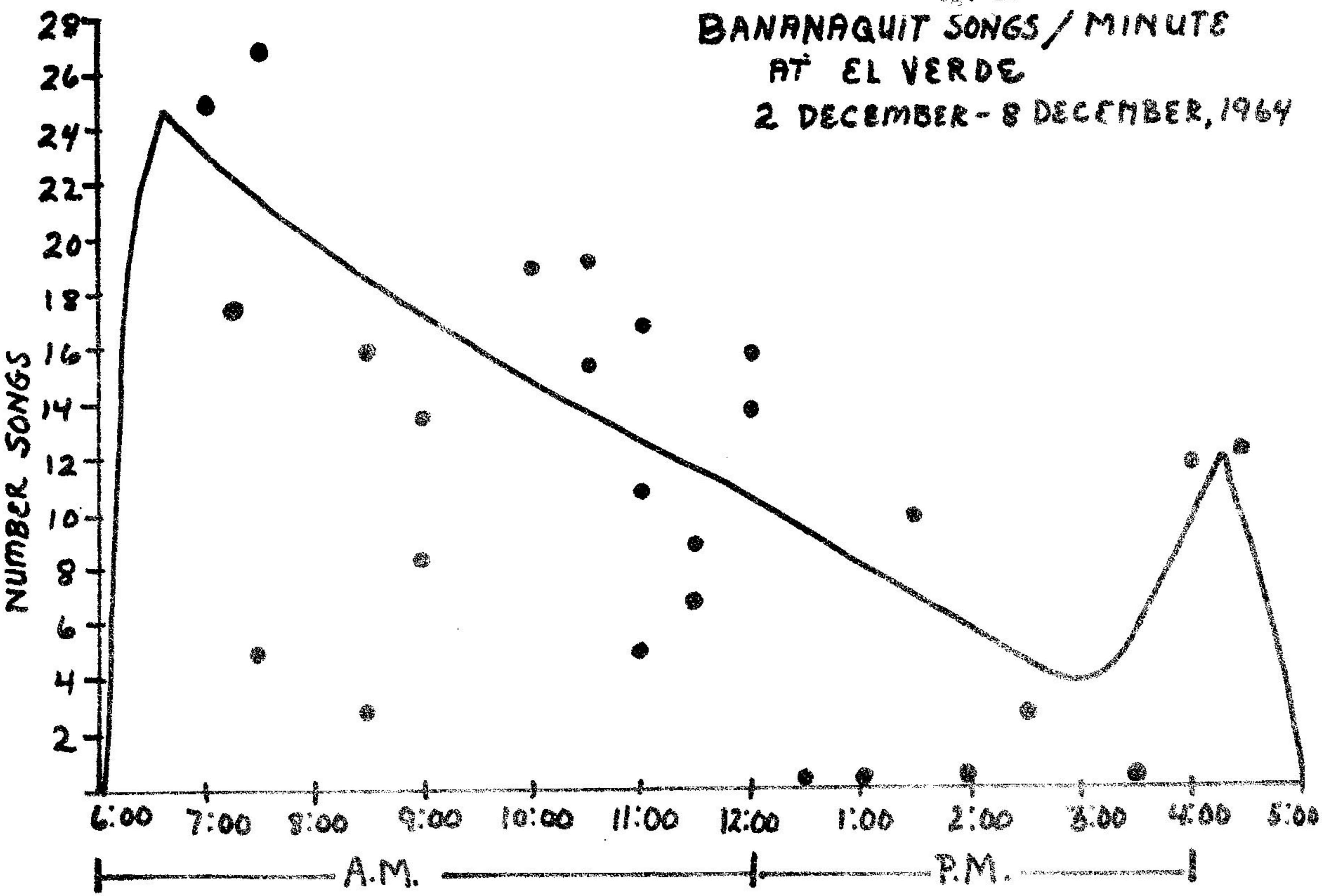


Fig. 18

BANANAQUIT SONGS / MINUTE
AT EL VERDE
2 DECEMBER - 8 DECEMBER, 1964

The Phosphate Cycle

By

R.A. Luse, PRNC,
with assistance of G.A. Briscoe

In our previous report for 1963 the movement from litter to plant and soil of the plant macronutrient phosphorus in the tropical rainforest was noted with the aid of tracer P^{32}. The data indicated considerable absorption by plant roots of P released during leaf decay. Little loss of P seems due to leaching from the root zone by rainfall.

Further studies have concentrated on a survey of the total P content of various rain forest plant materials. Results obtained from chemical analysis (some with Technicon Auto-Analyzer) of acid digests of plant tissue are tabulated below.

While the data are unsufficiently replicated in most cases, certain trends seem evident. These are:

1) Plant species differ in P content from each other and at different sites, though the level of illumination is not a factor.

2) Mature leaves contain significantly less P than young leaves of the same tree.

3) Root content of P is equal to or higher than that of mature leaves, but this is less than that of the decomposing leaf matter in contact with the root.

4) Non-leaf debris is significantly lower in P than leaves ready to fall or the litter itself.

On the basis of these fragmentary results, one may hypothesise a picture of P movement in which P content is high in young leaves, where phosphorylated compounds are demanded by photosynthesis and nucleic acid duplication. This P is drained from the leaves as they mature, due to demands in new growth elsewhere. Upon fall and decomposition, the leaf tissue loses C.H, and O more rapidly than P, thus rising in apparent P content over that of the leaves themselves. Phosphorus is absorbed by the network of tree roots at or near the surface; this movement is rapid, so that P content of the roots is low.

Material	Total phosphorus content, as mgm P/gm. dry tissue*
Leaves	
a. Young Tabonuco sp. - site 1	0.19
b. " " " - site 2	.39
c. " " " - site 3	.91
d. Mature " " - site 3	.69
e. Fallen " " - site 3	.17, .21; 0.19 aver.
f. Young Dacryodes excelsa (#2695), leaves in sun	.108, .080, .085, .108, .086; 0.93 aver.
g. Young Dacryodes excelsa (#2695), leaves in shade	.100, .125, .106, .086, .056; 0.95 aver.
h. Mature Dacryodes excelsa	.33, .34; 0.34 aver.
i Young Manilkara nitida (#2680), leaves in sun	1.10, 2.32, 2.89; 2.1 aver.
j. Mature Dryopterid deltoida	0.28, .31; 0.30 aver.
Roots	
k. Tabonuco sp., near soil surface	0.66
Other	
l. Organic matter in contact with root (k)	1.34
m. Rotted wood	0.15, .14; 0.14 aver.

* Values represent replicated samples taken of the material

Chemical Analyses of Trees at El Verde

from J. D. Ovington
Monk's Wood Experimental Station, England

As listed in the last years annual report, some representative trees were cut, weighed and sampled during November 1963 by the project team during Dr. Ovington's working trip. During the remainder of the year Mrs. Jan Briscoe prepared samples for chemical analyses by drying and powdering in Wiley Mills with the aid of the Soils Division of the University of Puerto Rico Agricultural Experiment Station through the courtesy of Dr. Alonso Riera. The main portion of each sample of leaves, wood, limbs, etc. was then sent to Dr. Ovington for chemical analysis by the Chemical Service of his organization, The Nature Conservancy Woodland Research Section, Monks Wood Experimental Station, England. In the first 3 months of 1964 roots of the felled trees were dug out by Alejo Estrada Pinto, Juan Maisonet, and Doroteo Martínez García, and these were also processed for analyses. The raw tables are included below. Ultimately, the chemical content of forest components are to be computed by combining these data and the data collected by the Tropical Terrain Detachment on trees out to 30 meters in the two study area circles.

Table 1

Chemical data on forest components at the El Verde Site.
Numbers are percent of oven dry weight.

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Small roots									
	Meliosma herbertii	Mh	1	0.08	0.42	0.42	0.38	0.041	0.81
		Mh#2	2	0.10	0.58	0.16	0.32	0.032	0.48
	Banisteria laurifola	Bl 50	3	0.06	0.17	0.78	0.12	0.031	0.78
	Buchenavia capitata	Bc 18	4	0.01	0.13	0.46	0.08	0.019	0.39
		Bc 22	5	0.03	0.13	0.75	0.09	0.023	0.52
		Bc 94	6	0.02	0.09	0.70	0.13	0.025	0.60
	Byrsonema spicata	Bs 7	7	0.03	0.26	0.47	0.25	0.026	0.42

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Small roots									
	Casearia arborea	Ca 43	8	0.04	0.68	0.15	0.17	0.032	0.64
		Ca 9	9	0.10	0.46	0.22	0.34	0.026	0.39
		Ca 87	10	0.03	0.82	0.16	0.24	0.032	0.55
	Casearia bicolor	Cbi 53	11	0.54	0.52	0.33	0.42	0.032	0.77
	Casearia sylvestris	Cs	12	0.26	0.74	0.39	0.24	0.027	0.89
	Calyognium squamulosum	Csq 54	13	0.05	0.17	0.69	0.13	0.024	0.68
		Csq 53	14	0.05	0.17	0.61	0.12	0.025	0.64
	Cecropia peltata	Cp 19	15	0.03	0.60	0.37	0.70	0.040	0.65
		Cp 48	16	0.05	0.30	0.44	0.60	0.028	0.53
		Cp 84	17	0.09	0.36	0.35	0.80	0.032	0.96
	Cordia borinquensis	Cb 56	18	0.60	1.18	0.42	0.15	0.038	1.24
		Cb 24	19	0.29	0.76	0.60	0.16	0.025	0.82
		Cb 35	20	I.S	I.S	I.S	I.S	I.S	1.05
		Cb 28	21	0.07	0.64	0.42	0.65	0.042	0.75
		Cb#2	22	0.08	0.74	0.24	0.70	0.040	0.69
		Cb 91	23	0.13	0.56	0.17	0.65	0.058	0.72
	Cordia sulcata	Csl 42	24	0.22	1.40	0.64	0.26	0.035	0.98
	Cyrilla racemiflora	Cr 101	1	0.11	0.10	0.22	0.13	0.015	0.55
	Drypetes glauca	Dg 10	2	0.13	0.70	0.61	0.14	0.032	0.55
	Didymopanax morototoni	Dm 81	3	0.05	0.60	0.95	0.31	0.033	0.87
	Drypetes glauca	Dg 17	4	0.04	0.13	0.74	0.30	0.024	0.59
	Dacryodes excelsa	De 20	5	0.03	0.07	0.36	0.11	0.026	0.64

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Small roots									
	Dacryodes excelsa	De 90	6	0.07	0.18	0.30	0.09	0.024	0.69
		De 51	7	0.09	0.30	0.26	0.08	0.034	0.55
		De 102	8	0.03	0.15	0.38	0.06	0.028	0.64
		De 21	9	0.06	0.50	0.41	0.11	0.061	0.94
		De 54	10	0.04	0.34	0.59	0.12	0.025	0.43
	Eugenia stahlii	Es 5	11	0.10	0.26	0.99	0.23	0.033	0.46
		Es 15	12	0.14	0.20	1.54	0.18	0.025	0.52
		Es#6	13	0.13	0.21	0.68	0.24	0.023	0.48
		Es 36	14	0.07	0.26	0.89	0.24	0.022	0.44
		Es #3	15	0.20	0.20	1.08	0.31	0.030	0.64
	Hirtella rugosa	Hr 83	16	0.01	0.09	0.35	0.20	0.036	0.89
		Hr 70	17	0.02	0.09	0.14	0.25	0.020	0.47
		Hr 57	18	I.S	I.S	I.S	I.S.	I.S	0.38
		Il#6	19	0.07	0.38	0.57	0.16	0.034	1.00
	Inga vera	Iv 1	20	I.S	0.52	0.72	0.11	0.029	1.07
	Ixoria ferrea	If 60	21	0.08	0.56	0.73	0.06	0.021	0.95
		If 89	22	0.03	0.36	0.38	0.07	0.028	0.84
	Miconia prasina	Mp 27	23	0.03	0.22	0.19	0.07	0.020	0.55
		Mp 34	24	0.03	0.28	0.17	0.05	0.021	0.47
		Mp 72	25	0.05	0.21	0.24	0.07	0.020	0.47
		Mp 95	26	0.10	0.34	0.71	0.11	0.027	0.51
	Miconia tetandra	Mt 71	1	0.05	0.22	0.20	0.08	0.019	0.42
		Mt 90	2	0.02	0.20	0.16	0.11	0.032	0.74
	Micropholis garciniae-folia	Mg 51	3	0.29	0.08	0.30	0.06	0.021	0.65
		Mg 52	4	0.12	0.19	1.94	0.11	0.026	0.78
		Mg 101	5	0.13	0.20	1.82	0.09	0.027	0.88
	Matayba domingensis	Md 55	6	0.03	0.34	0.54	0.17	0.030	0.52

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Small roots	Matayba domingensis	Md #99	7	0.04	0.52	0.80	0.16	0.047	0.52
		Md	8	0.03	0.50	0.62	0.12	0.029	0.51
	Myrcia berberis	Mb 56	9	0.05	0.15	1.00	0.14	0.029	0.75
	Manilkara nitida	Mn	10	0.02	0.58	0.54	0.11	0.035	0.29
		Mn 14	11	0.30	0.36	0.42	0.10	0.019	0.55
		Mn 45	12	0.45	0.18	0.26	0.17	0.026	0.63
		Mn 95	13	0.37	0.30	0.42	0.04	0.019	0.47
	Myrcia splendens	Ms 8	14	0.02	0.28	0.34	0.10	0.033	0.54
		Ms 73	15	0.01	0.28	0.22	0.12	0.031	0.48
	Ocotea leucoxylon	Ol 41	16	0.02	0.70	0.54	0.03	0.031	0.75
		Ol 61	17	0.03	0.52	0.66	0.05	0.024	0.74
		Ol	18	0.02	0.60	0.84	0.08	0.034	0.99
	Ocotea portoricensis	Op	19	0.01	0.28	0.26	0.05	0.029	0.82
	Ocotea spathulata	Os 97	20	0.08	0.26	0.80	0.06	0.038	0.82
	Ormosia krugii	Ok 51	21	0.18	0.15	0.26	0.06	0.041	1.32
	Palicourea riparia	Pr #4	1	0.10	0.36	0.16	0.11	0.029	0.70
		Pr 25	2	0.14	0.40	0.30	0.08	0.032	0.93
		Pr 26	3	0.12	0.28	0.22	0.06	0.020	0.55
		Pr 37	4	0.09	0.52	0.42	0.14	0.046	0.95
		Pr 55	5	0.07	0.32	0.30	0.05	0.022	0.70
		Pr 57	6	0.05	0.42	0.38	0.07	0.027	0.74
		Pr 59	7	0.09	0.66	0.38	0.07	0.040	1.32
		Pr 92	8	0.19	0.36	0.34	0.09	0.029	1.12
		Pr 15	9	0.03	0.36	0.46	0.16	0.036	0.78
	Psychotria berteriana	Pb 29	10	0.41	0.40	0.54	0.07	0.027	0.09
		Pb 39	11	0.29	0.48	0.58	0.07	0.030	0.82
		Pb 44	12	0.15	0.74	0.42	0.20	0.046	1.17

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Small roots									
	Sloanea berteriana	Sb 13	13	0.01	0.36	0.42	0.17	0.034	0.63
		Sb 23	14	0.03	0.18	0.80	0.20	0.023	0.42
		Sb 38	15	0.00	1.04	0.76	0.13	0.071	1.04
	Casearia bicolor	Cbi 33	16	0.36	0.30	0.46	0.07	0.018	0.54
		Se 11	17	0.08	0.21	0.58	0.13	0.025	0.55
	Rourea glabra	Rg 12	18	0.12	0.18	0.38	0.11	0.022	0.72
		Rg 31	19	I.S	I.S	I.S	I.S	I.S	0.52
	Tabebuia heterophylla	Th 16	20	0.10	0.40	0.26	0.11	0.031	0.37
		Th 62	21	0.10	0.50	0.50	0.16	0.038	0.48
Large & Medium Roots	Buchenavia capitata	Bc 18	1	0.01	0.12	0.34	0.03	0.023	0.33
		Bc 22	2	0.01	0.09	0.00	0.06	0.017	0.26
		Bc 94	3	0.01	0.14	0.40	0.05	0.025	0.39
	Banisteria laurifolia	Bl 50	4	0.01	0.28	0.87	0.10	0.023	0.59
	Brysonema spicata	Bs 7	5	0.01	0.26	0.46	0.22	0.025	0.33
	Casearia arborea	Ca 9	6	0.11	0.44	0.29	0.34	0.023	0.42
		Ca 43	7	0.02	0.06	0.19	0.20	0.025	0.41
		Ca 87	8	0.04	0.70	0.19	0.22	0.029	0.38
	Casearia bicolor	Cbi 33	9	0.45	0.46	0.58	0.28	0.015	0.31
		Cbi 53	10	0.38	0.46	0.40	0.28	0.018	0.40
	Casearia sylvestris	Cs 86	11	0.28	0.32	0.97	0.16	0.022	0.56
	Cecropia peltata	Cp 19	12	0.01	0.48	0.34	0.36	0.022	0.59
		Cp 48	13	0.05	0.17	0.21	0.32	0.012	0.22
		Cp 84	14	0.02	0.34	0.31	0.16	0.010	0.19

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Large & Medium roots									
	Cordia borinquensis	Cb 24	15	0.36	0.72	0.67	0.14	0.017	0.58
	Casearia sylvestris	Csa 2	16	0.03	0.52	0.25	0.58	0.038	0.57
		Csa 28	17	0.01	0.58	0.23	0.52	0.044	0.46
		Csa 53	18	0.07	0.17	0.87	0.08	0.025	0.70
		Csa 91	19	0.12	0.40	0.38	0.50	0.045	0.59
	Cordia sulcata	Cs 42	20	0.18	0.84	0.89	0.20	0.018	0.54
	Cyrilla racemiflora	Cr 101	21	0.14	0.05	0.25	0.06	0.003	0.12
	Dacryodes excelsa	De 20	22	0.03	0.08	0.29	0.06	0.011	0.29
		De 21	23	0.04	0.19	0.29	0.06	0.017	0.22
		De 39	24	0.25	0.30	0.58	0.07	0.021	I.S
		De 51	25	0.02	0.19	0.19	0.05	0.016	0.19
		De 90	26	0.04	0.11	0.19	0.05	0.010	0.34
		De 102	27	0.06	0.13	0.42	0.07	0.011	0.21
	Didymopanax morototoni	Dm 81	1		0.72	0.79	0.13	0.021	0.43
		Dm 82	2		0.52	0.73	0.13	0.020	0.44
	Drypetes glauca	Dg 17	3		0.17	0.63	0.21	0.019	0.39
	Eugenia stahlii	Es 3	4		0.16	0.67	0.14	0.024	0.50
		Es 5	5		0.13	0.58	0.09	0.015	0.26
		Es 15	6		0.15	0.95	0.08	0.022	0.33
		Es 46	7		0.19	0.65	0.11	0.022	0.54
	Inga sp.	Il 46	8		0.21	0.65	0.06	0.018	0.59
	Inga vera	Iv 1	9		0.21	0.36	0.03	0.015	0.49
	Ixora ferrea	If 60	10		0.28	0.97	0.07	0.016	0.55
		If 89	11		0.20	0.36	0.06	0.028	0.53

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Large & Medium Roots									
	Hirtella rugosa	Hr 57	12		0.10	0.38	0.19	0.022	0.37
		Hr 58	13		0.16	0.17	0.12	0.016	0.28
		Hr 70	14		0.09	0.15	0.22	0.020	0.51
		Hr 83	15		0.07	0.23	0.14	0.018	0.45
		Hr 95	16		0.21	0.50	0.09	0.016	0.33
	Miconia prasina	Mp 27	17		0.32	0.36	0.06	0.013	0.32
		Mp 34	18		0.28	0.31	0.05	0.017	0.36
	Miconia tetranda	Mt 71	19		0.32	0.25	0.07	0.012	0.33
		Mt 90	20		0.30	0.11	0.04	0.011	0.36
	Micropholis garceniaefolia	Mg 5	21		0.05	0.25	0.06	0.015	0.38
		Mg 52	22		0.12	0.95	0.11	0.020	0.43
		Mg 101	23		0.20	1.44	0.07	0.023	0.54
Large Roots									
	Matayba domingensis	Md 55	1		0.12	0.20	0.08	0.019	0.12
		Md 99	2		0.20	0.50	0.08	0.025	0.34
	Myrcia berberis	Mb 56	3		0.14	0.42	0.04	0.015	0.36
	"Maya"	4	4		0.42	0.38	0.05	0.029	0.26
	Manilkara nitida	Mn 14	5		0.36	0.34	0.05	0.011	0.23
		Mn 30	6		0.26	0.54	0.08	0.012	0.33
		Mn 95	7		0.26	0.22	0.05	0.008	0.15
	Ocotea leucoxylon	Ol	8		0.28	0.46	0.09	0.025	0.41
		Ol 41	9		0.58	0.50	0.05	0.029	0.47
		Ol 85	10		0.38	0.06	0.02	0.023	0.55
		Ol 61	11		0.18	0.46	0.01	0.015	0.09
	Ocotea portoricensis	Op 2	12		0.26	0.38	0.03	0.032	0.00
	Ocotea spathulata	Os 97	13		0.26	0.30	0.02	0.033	0.77

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Large roots									
	Ormosia krugii	Ok 51	14		0.09	0.26	0.02	0.026	1.00
	Palicourea riparia	Pr 4	15		0.48	0.22	0.08	0.026	0.01
		Pr 25	16		0.28	0.20	0.05	0.021	0.58
		Pr 26	17		0.30	0.30	0.05	0.017	0.34
		Pr 37	18		0.52	0.38	0.05	0.028	0.06
		Pr 55	19		0.34	0.34	0.01	0.022	0.56
		Pr 57	20		0.48	0.46	0.02	0.019	0.59
		Pr 59	21		0.06	0.46	0.08	0.033	0.91
		Pr 92	22		0.36	0.22	0.05	0.020	0.84
		#3	23		0.48	0.92	0.58	0.025	0.57
		#5	04		0.28	0.46	0.12	0.031	0.59
	Psychotria berteriana	Pb 29	1		0.36	0.38	0.05	0.020	0.42
		Pb 44	2		0.56	0.27	0.06	0.032	0.53
	Rourea glabra	Rg 12	3		0.28	0.56	0.13	0.022	0.00
		Rg 31	4		0.15	0.27	0.11	0.022	0.36
	Sloanea berteriana	Sb 13	5		0.24	0.56	0.11	0.019	0.08
		Sb 23	6		0.11	0.50	0.13	0.014	0.26
		Sb 11	7		0.18	0.73	0.12	0.022	0.36
	Tabebuia heterophylla	Th 16	8		0.28	0.19	0.07	0.016	0.23
		Th 40	9		0.38	0.19	0.09	0.017	0.30
		Th 62	10		0.36	0.34	0.11	0.036	0.51
Butt roots									
	Aguacatillo	#1	1		0.40	0.29	0.28	0.034	0.37
	Buchenavia capitata	Bc 2	2		0.50	0.21	0.14	0.027	0.29
		Bc 18	3		0.11	0.23	0.04	0.018	0.28
		Bc 22	4		0.10	0.33	0.03	0.017	0.32
		Bc 40	5		0.30	0.21	0.08	0.013	0.23
		Bc 94	6		0.09	0.44	0.04	0.016	0.27

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Butt roots									
	Banisteria laurifolia	Bl 50	7		0.20	0.71	0.12	0.022	0.57
	Casearia arborea	Ca 9	8		0.50	0.25	0.26	0.023	0.32
		Ca 43	9		0.56	0.13	0.16	0.026	0.31
		Ca 87	10		0.68	0.52	0 18	0.033	0.41
	Casearia bicolor	Cb 33	11		0.28	0.27	0.15	0.013	0.21
		Cb 53	12		0.34	0.58	0.20	0.013	0.26
	Calycogonium squamulosum	Csq53	13		0.17	0.44	0.06	0.023	0.56
		Csq54	14		0.28	0.33	0.11	0.021	0.43
	Cecropia peltata	Cep19	15		0.52	0.27	0.30	0.019	0.19
		Cep48	16		0.19	0.27	0.30	0.016	0.38
		Cep84	17		0.48	0.23	0.19	0.014	0.25
	Cordia borinquensis	Cb 24	18		0.74	0.87	0.10	0.032	0.48
		Cb 35	19		0.68	0.44	0.12	0.039	0.56
		Cb 38	20		0.52	0.33	0.08	0.033	0.67
		Cb 56	21		0.58	0.46	0.07	0.038	0.54
	Cyrilla racemiflora	Cr 61	22		0.21	0.46	0.05	0.010	0.22
	Cordia sulcata	Cs 42	23		0.52	0.38	0.08	0.020	0.31
		Cs 86	24		0.50	0.48	0.08	0.016	0.29
	Casearia sylvestris	Cs #2	1		0.42	0.23	0.52	0.037	0.45
		Cs 28	2		0.56	0.36	0.50	0.041	0.47
		Cs 91	3		0.30	0.46	0.56	0.041	0.47
	Dacryodes excelsa	De 20	4		0.12	0.11	0.03	0.010	0.16
		De 20	5		0.17	0.44	0.06	0.009	0.21
		De 21	6		0.16	0.11	0.03	0.009	0.22
		De 51	7		0.26	0.15	0.03	0.015	0.14
		De 54	8		0.18	0.27	0.06	0.011	0.18
		De 90	9		0.28	0.25	0.07	0.015	0.28

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Butt roots									
	Dacryodes excelsa	De 102	10		0.22	0.40	0.09	0.017	0.24
	Didymopanax morototoni	Dm 81	11		0.40	0.31	0.08	0.016	0.39
		Dm 82	12		0.26	0.25	0.08	0.012	0.21
	Drypetes glauca	Dg 10	13		0.40	0.48	0.05	0.025	0.40
		Dg 17	14		0.28	0.60	0.28	0.022	0.40
	Eugenia stahlii	Es 15	15		0.15	0.65	0.08	0.018	0.25
		Es 15	16		0.15	0.48	0.06	0.018	0.25
		Es 36	17		0.28	0.75	0.15	0.018	0.28
		Es 46	18		0.18	0.46	0.11	0.020	0.34
	Inga sp.	Il 46	19		0.32	0.29	0.04	0.016	0.35
		Il 49	20		0.26	0.42	0.04	0.013	0.41
	Inga vera	Iv 1	21		0.20	0.17	0.03	0.011	0.48
	Ixora ferrea	If 60	22		0.18	0.42	0.03	0.012	0.29
		If 89	23		0.13	0.38	0.06	0.025	0.29
	Hirtella rugosa	Hr 57	1		0.08	0.25	0.12	0.021	0.32
		Hr 58	2		0.15	0.11	0.11	0.011	0.18
		Hr 70	3		0.09	0.15	0.14	0.015	0.26
		Hr 83	4		0.09	0.23	0.12	0.016	0.31
	Miconia prasina	Mp 27	5		0.32	0.29	0.06	0.014	0.29
		Mp 34	6		0.36	0.40	0.06	0.026	0.34
		Mp 71	7		0.32	0.44	0.06	0.013	0.21
		Mp 72	8		0.30	0.31	0.07	0.010	0.22
		Mp 95	9		0.18	0.44	0.06	0.016	0.23
	Miconia tetrandra	Mt 90	10		0.21	0.10	0.04	0.015	0.21
	Micropholis garciniaefolia	Mg 5	1		0.04	0.13	0.04	0.008	0.24

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Butt roots									
	Micropholis garciniaefolia	Mg 52	12		0.12	0.40	0.11	0.017	0.33
		Mg 101	13		0.16	0.69	0.07	0.023	0.42
	Matayba domingensis	Md 55	14		0.11	0.29	0.05	0.014	0.14
		Md #99	15		0.19	0.50	0.06	0.023	0.28
	Myrcia berberis	Mb 56	16		0.16	0.44	0.06	0.013	0.28
	"Maya"	4	17		0.38	0.27	0.05	0.026	0.15
	Manilkara nitida	Mn 14	18		0.19	0.23	0.03	0.007	0.13
		Mn 30	19		0.17	0.23	0.05	0.006	0.16
		Mn 45	20		0.15	0.27	0.06	0.013	0.25
		Mn 95	21		0.24	0.34	0.05	0.006	0.13
	Myrcia splendens	Ms 8	22		0.32	0.38	0.06	0.026	0.30
		Ms 73	23		0.32	0.21	0.06	0.027	0.49
	Ocotea leucoxylon	Ol 41	1		0.44	0.61	0.02	0.026	0.33
		Ol 61	2		0.28	0.73	0.03	0.021	0.64
		Ol 85	3		0.28	0.69	0.03	0.023	0.45
		Ol 100	4		0.20	0.23	0.07	0.018	0.25
	Ocotea portoricensis	Op 2	5		0.20	0.29	0.02	0.024	0.52
	Ocotea spathulata	Os 97	6		0.19	0.11	0.02	0.029	0.56
	Ormosia krugii	Ok 51	7		0.08	0.10	0.02	0.015	0.47
	Palicourea riparia	Pr #4	8		0.48	0.19	0.02	0.024	0.44
		Pr 25	9		0.38	0.15	0.01	0.030	0.70
		Pr 26	10		0.28	0.42	0.06	0.018	0.39
		Pr 55	11		0.34	0.15	0.02	0.015	0.34
		Pr 57	12		0.40	0.17	0.01	0.018	0.48
		Pr 59	13		0.54	0.31	0.04	0.031	0.78
		Pr 92	14		0.32	0.17	0.04	0.014	0.59

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Butt roots									
	Palo blanco	Pb 3	15		0.42	0.61	0.50	0.032	0.64
	Palo de pollo	Pp 5	16		0.14	0.27	0.08	0.026	0.61
	Psychotria berteriana	Pb 29	18		0.36	0.29	0.04	0.016	0.27
		Pb 39	17		0.30	0.29	0.04	0.021	0.31
		Pb 44	19		0.48	0.21	0.03	0.020	0.24
	Sloanea berteriana	Sb 13	20		0.17	0.50	0.04	0.013	0.20
		Sb 23	21		0.16	0.61	0.08	0.015	0.27
		Se 11	22		0.26	0.69	0.06	0.019	0.20
	Tabebuia heterophylla	Th 16	23		0.17	0.11	0.01	0.012	0.18
		Th 62	24		0.34	0.17	0.04	0.022	0.38
Boles									
	Alchorneopsis portoricensis	Ap 74	1		0.13	0.19	0.09	0.020	0.31
	Banisteria laurifolia	Bl 50	2		0.24	0.48	0.09	0.039	0.58
	Byrsonima spicata	Bs 7	3		0.24	0.48	0.08	0.033	0.35
	Buchenavia capitata	Bc 18	4		0.20	0.27	0.03	0.022	0.25
		Bc 22	5		0.13	0.50	0.05	0.017	0.28
		Bc 90	6		0.19	0.36	0.04	0.024	0.26
	Casearia arborea	Ca 9	7		0.48	0.21	0.13	0.036	0.33
		Ca 43	8		0.52	0.15	0.09	0.029	0.26
		Ca 87	9		0.62	0.21	0.09	0.029	0.34
	Casearia guianensis	Cg 78	10		1.18	0.34	0.18	0.036	0.87
	Casearia bicolor	Cbi 24	11		0.36	0.25	0.06	0.038	0.21

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Boles									
	Casearia bicolor	Cbi 33	12		0.36	0.56	0.16	0.023	0.34
		Cbi 53	13		0.38	0.38	0.21	0.019	0.30
	Casearia sylvestris	Cs 2	14		0.52	0.36	0.32	0.034	0.44
		Cs 28	15		0.92	0.36	0.24	0.054	0.65
		Cs 91	16		0.58	0.33	0.22	0.036	0.48
	Calycogonium squamulosum	Cys 54	17		0.21	0.91	0.08	0.014	0.34
	Cecropia peltata	Cep 19	18		0.62	0.40	0.32	0.029	0.40
		Cep 48	19		0.40	0.29	0.22	0.017	0.17
		Cep 84	20		0.28	0.19	0.17	0.010	0.12
	Cordia boringensis	Cb 35	21		0.40	0.54	0.16	0.032	0.46
		Cb 38	22		0.40	0.34	0.11	0.037	0.50
		Cb 56	23		0,40	0.42	0.08	0.033	0.44
	Cordia sulcata	Csl 42	24		0.58	0.38	0.13	0.025	0.28
		Csl 85	25		0.28	0.36	0.13	0.014	0.26
	Cyrilla racemiflora	Cr 106	1		0.07	0.13	0.11	0.005	0.12
	Dacryodes excelsa	De 20	2		0.15	0.17	0.03	0.005	0.13
		De 21	3		0.17	0.33	0.04	0.011	0.11
		De 51	4		0.13	0.08	0.02	0.067	0.13
		De 54	5		0.21	0.15	0.04	0.014	0.18
		De 96	6		0.19	0.19	0.04	0.009	0.13
		De 107	7		0.16	0.15	0.03	0.011	0.14
	Didymopanax morototoni	Dm 81	8		0.28	0.31	0.10	0.008	0.16
		Dm 82	9		0.36	0.31	0.11	0.013	0.17
	Drypetes glauca	Dg 10	10		0.44	0.85	0.06	0.033	0.45
		Dg 17	11		0.28	0.40	0.18	0.022	0.42

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Boles									
	Eugenia stahlii	Es 3	12		0.21	0.75	0.11	0.024	0.44
		Es 5	13		0.20	0.48	0.07	0.019	0.28
		Es 6	14		0.24	0.46	0.06	0.021	0.28
		Es 15	15		0.19	0.56	0.06	0.018	0.27
		Es 36	16		0.30	0.79	0.10	0.025	0.36
	Hirtella rugosa	Hr 57	17		0.16	0.17	0.09	0.025	0.23
		Hr 70	18		0.14	0.21	0.09	0.017	0.26
		Hr 83	19		0.10	0.19	0.09	0.013	0.20
		Hr 46	20		0.32	0.23	0.08	0.017	0.31
		Hr 47	21		0.48	0.40	0.05	0.020	0.52
		Hr 49	22		0.19	0.44	0.03	0.013	0.40
		Hr 1	23		0.17	0.29	0.02	0.011	0.28
	Ixora ferrea	If 60	24		0.21	0.40	0.03	0.013	0.20
		If 88	25		0.13	0.36	0.05	0.026	0.16
	Magnolia splendens	Mgs103	1		0.10	0.25	0.05	0.043	0.46
		Mgs105	2		0.06	0.25	0.04	0.096	0.33
	Manilkara nitida	Mn 14	3		0.17	0.21	0.03	0.006	0.14
		Mn 30	4		0.12	0.31	0.05	0.008	0.22
		Mn 45	5		0.17	0.21	0.06	0.011	0.23
		Mn 97	6		0.15	0.19	0.04	0.008	0.14
	Marcgravia rectiflora	Mr109	7		1.54	0.77	0.46	0.051	0.50
	Matayba domingensis	Md 55	8		0.12	0.29	0.03	0.013	0.13
		Md 95	9		0.24	0.46	0.04	0.027	0.36
		Md 99	10		0.24	0.44	0.04	0.023	0.35
	Meliosma herbertii	Mh 76	11		0.96	0.40	0.12	0.035	0.40
		Mh 77	12		0.62	0.56	0.18	0.032	0.46
	Micropholis garciniaefolia	Mg 52	13		0.07	0.54	0.05	0.016	0.44
		Mg 102	14		0.07	0.44	0.05	0.013	0.30

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Boles									
	Psychotria berteriana	Pb 29	15		0.50	0.31	0.07	0.017	0.38
		Pb 39	16		0.36	0.36	0.07	0.017	0.35
		Pb 44	17		0.34	0.23	0.05	0.019	0.33
	Philodendron krebsii	Pk108	18		3.00	1.71	0.20	0.069	0.69
	Rourea glabra	Rg 12	19		0.19	0.54	0.11	0.022	0.44
		Rg 50	20		0.21	0.61	0.15	0.026	0.41
	Sloanea berteriana	Sb 11	21		0.28	0.71	0.06	0.018	0.28
		Sb 13	22		0.20	0.46	0.04	0.010	0.21
		Sb 23	23		0.15	0.36	0.06	0.015	0.24
	Tabebuia heterophylla	Th 16	24		0.21	0.21	0.06	0.023	0.29
		Th 40	25		0.52	0.27	0.11	0.023	0.31
		Th 62	26		0.28	0.27	0.10	0.024	0.30
	Tetragastris balsamifera	Tb 75	27		0.56	0.25	0.06	0.034	0.34
Branches	Alchorneopsis portoricensis	Ap 74	1		0.32	0.19	0.08	0.032	0.48
	Banisteria laurifolia	Bl 50	2		0.36	0.93	0.13	0.048	0.60
	Byrsonema spicata	Bs 7	3		0.44	1.07	0.16	0.045	0.78
	Buchenavia capitata	Bc 18	4		0.38	0.58	0.06	0.024	0.38
		Bc 22	5		0.24	1.33	0.12	0.038	0.69
		Bc 90	6		0.28	0.44	0.04	0.027	0.35
	Casearia arborea	Ca 9	7		0.72	0.21	0.09	0.078	0.77
		Ca 43	8		0.84	0.17	0.16	0.054	0.86
		Ca 87	9		0.96	0.13	0.11	0.038	0.72
	Casearia bicolor	Cbi24	10		0.80	0.46	0.21	0.086	1.11
		Cbi33	11		0.42	0.38	0.23	0.033	0.61
		Cbi53	12		0.64	0.29	0.23	0.027	0.48

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Branches									
	Casearia guianensis	Cg 78	13		0.82	0.17	0.18	0.032	0.56
	Casearia sylvestris	Cs 28	14		1.80	0.42	0.28	0.070	1.14
		Cs 91	15		1.00	0.29	0.20	0.049	0.75
	Calycogonium squamulosum	Cys53	16		0.32	1.50	0.16	0.035	1.03
		Cys54	17		0.32	1.21	0.11	0.024	0.57
	Cecropia peltata	Cep48	18		1.40	0.46	0.34	0.060	0.62
		Cep84	19		0.70	0.40	0.16	0.030	0.55
	Cordia borinquensis	Cb 35	20		0.56	0.61	0.42	0.038	0.87
		Cb 38	21		0.28	0.46	0.26	0.040	0.72
		Cb 56	22		0.66	0.83	0.28	0.042	0.83
	Cordia sulcata	Cs142	23		1.06	0.56	0.32	0.050	0.59
		Cs185	24		1.58	0.56	0.24	0.076	0.63
	Cyrilla racemiflora	Cr106	1		0.09	0.20	0.07	0.023	0.26
	Casearia sylvestris	Cs 2	2		1.34	0.38	0.80	0.043	0.81
	Dacryodes excelsa	De 20	3		0.30	0.54	0.12	0.038	0.46
		De 21	4		0.28	0.30	0.06	0.020	0.23
		De 51	5		0.20	0.16	0.03	0.019	0.19
		De 54	6		0.42	0.72	0.11	0.020	0.53
		De 96	7		0.17	0.38	0.07	0.017	0.32
		De107	8		0.20	0.38	0.12	0.026	0.35
	Didymopanax morototoni	Dm 81	9		0.66	1.16	0.19	0.024	0.48
	Drypetes glauca	Dg 10	10		0.96	1.58	0.28	0.069	1.06
		Dg 17	1		0.50	0.42	0.16	0.029	0.59
	Eugenia stahlii	Es 3	12		0.38	0.96	0.16	0.044	0.59

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Branches									
	Eugenia stahlii	Es 5	13		0.40	1.30	0.18	0.035	0.50
		Es 6	14		0.34	1.16	0.17	0.039	0.53
		Es 15	15		0.18	0.88	0.10	0.044	0.57
		Es 36	16		0.30	0.92	0.14	0.020	0.42
	Hirtella rugosa	Hr 57	17		0.58	0.76	0.05	0.030	0.60
		Hr 58	18		0.28	0.54	0.11	0.027	0.40
		Hr 70	19		0.26	0.46	0.14	0.032	0.47
		Hr 83	20		0.17	0.30	0.09	0.024	0.31
		Hr 46	21		0.44	0.72	0.06	0.034	0.70
		Hr 47	22		0.66	0.68	0.12	0.052	1.05
		Hr 49	23		0.40	1.12	0.07	0.040	1.08
		Hr 1	24		0.17	0.26	0.02	0.014	0.46
	Ixora ferrea	If 88	1		0.52	1.00	0.26	0.042	0.64
	Magnolia splendens	Ms103	2		0.28	0.62	0.13	0.197	0.63
	Manilkara nitida	Mn 14	3		0.22	0.30	0.07	0.014	0.22
		Mn 30	4		0.18	0.50	0.11	0.016	0.39
		Mn 45	5		0.56	0.46	0.12	0.031	0.56
		Mn 97	6		0.28	0.38	0.06	0.027	0.42
	Matayba domingensis	Md 55	7		0.17	0.50	0.06	0.018	0.20
		Md 95	8		0.32	1.26	0.11	0.034	0.70
		Md 99	9		0.48	1.04	0.08	0.049	0.69
	Miconia tetrandra	Mt 79	10		0.32	0.80	0.03	0.016	0.36
		Mt 88	11		0.38	1.20	0.08	0.028	0.58
	Miconia prasina	Mp 27	12		0.36	1.20	0.04	0.022	0.55
		Mp 34	13		0.36	0.92	0.02	0.019	0.47
		Mp 72	14		0.13	0.80	0.01	0.015	0.42
	Micropholis garciniae-folia	Mg 52	15		0.15	1.08	0.09	0.033	0.71
		Mg102	16		0.15	0.76	0.05	0.025	0.61

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Branches									
	Meliosma herbertii	Mh 77	17		1.30	1.22	0.36	0.044	0.88
	Myrcia berberis	Mb 56	18		0.26	1.38	0.11	0.021	0.54
	Myrcia splendens	Ms 8	19		0.52	0.62	0.11	0.051	0.61
		Ms 73	20		0.34	0.42	0.11	0.041	0.75
	Ocotea leucoxylon	Ol 41	21		1.10	1.04	0.11	0.065	1.10
		Ol 61	22		1.00	0.68	0.16	0.038	0.98
		Ol 86	23		0.50	0.80	0.07	0.032	0.57
	Ocotea portoricen-sis	Op104	24		0.26	0.54	0.05	0.028	0.56
	Ocotea spathulata	Os100	25		0.52	0.34	0.08	0.064	0.98
	Ormosia krugii	Ok 51	1		0.18	0.26	0.06	0.029	0.94
	Palicourea riparia	Pr 4	2		0.48	0.66	0.21	0.055	0.85
		Pr 25	3		0.52	0.88	0.24	0.058	1.33
		Pr 26	4		0.26	0.58	0.10	0.032	0.62
		Pr 47	5		0.54	0.84	0.31	0.040	0.78
		Pr 52	6		0.46	0.54	0.09	0.020	0.45
		Pr 55	7		0.58	0.80	0.06	0.034	0.69
		Pr 59	8		0.52	0.46	0.05	0.025	0.57
		Pr 92	9		0.42	0.26	0.07	0.021	0.69
	Psychotria berteriana	Pb 29	10		0.52	0.76	0.30	0.022	0.46
		Pb 39	11		0.92	1.50	0.40	0.042	0.79
		Pb 44	12		0.62	0.84	0.31	0.040	0.71
	Philodendron krebsii	Pk108	13		3.50	3.24	0.31	0.056	0.70
	Rourea glabra	Rg 12	14		0.52	0.72	0.19	0.042	0.62
		Rg 31	15		0.46	1.20	0.22	0.029	0.49
		Rg 97	16		0.28	0.72	0.11	0.024	0.38
		Rg101	17		0.62	0.34	0.10	0.051	0.37

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Branches									
	Sloanea berteriana	Sb 11	18		0.50	1.38	0.16	0.026	0.47
		Sb 13	19		0.54	0.92	0.11	0.027	0.60
		Sb 23	20		0.30	1.70	0.22	0.043	0.65
		Sb 60	21		0.62	1.08	0.13	0.026	0.53
	Tabebuia hetereophylla	Th 16	22		0.36	0.68	0.17	0.058	0.47
		Th 40	23		0.50	0.46	0.18	0.035	0.53
		Th 62	24		0.48	0.62	0.17	0.048	0.69
		Th 75	25		1.28	0.72	0.11	0.055	0.49
Leaves	Alchorneopsis portoricensis	Ap 74	1		1.04	1.16	0.32	0.116	2.63
	Banisteria laurifolia	Bl 50	2		1.08	1.00	0.44	0.096	1.99
	Byrsonima spicata	Bs 7	3		0.64	0.68	0.48	0.070	1.90
	Buchenavia capitata	Bc 22	4		0.56	1.16	0.32	0.097	2.12
		Bc 90	5		0.80	0.60	0.14	0.101	1.82
	Buchenavia capitata	Bc 18	6		1.84	0.68	0.42	0.122	1.42
		Bc 22	7		1.16	0.68	0.32	0.140	2.25
		Bc 90	8		0.80	0.76	0.16	0.070	1.08
	Casearia arborea	Ca 9	9		1.08	0.44	0.42	0.079	2.23
		Ca 43	10		0.88	0.40	0.32	0.084	2.40
		Ca 87	11		1.16	0.40	0.28	0.075	2.40
	Casearia bicolor	Cbi33	12		0.76	0.68	0.22	0.100	1.94
		Cbi53	13		0.92	0.84	0.28	0.095	2.23
			14		1.24	0.92	0.46	0.074	0.94
	Casearia guianensis	Cg 75	15		2.68	1.24	0.92	0.102	2.17
	Casearia sylvestris	Cs 25	16		2.88	1.00	0.92	0.101	2.00
		Cs 91	17		2.36	1.08	1.04	0.118	2.62

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Leaves									
	Calycogonium squamulosum	Cys 53	18		0.56	2.92	0.50	0.052	1.34
		Cys 54	19		0.84	2.92	0.60	0.045	1.62
	Cecropia peltata	Cep19	20		1.36	1.32	0.44	0.091	1.76
		Cep48	21		1.32	1.16	0.64	0.109	1.76
		Cep84	22		1.20	1.08	0.32	0.125	1.85
	Cordia borinquensis	Cb 35	1		0.80	1.44	0.76	0.081	1.70
		Cb 38	2		0.72	1.76	0.84	0.081	1.67
		Cb 56	3		1.32	0.92	0.64	0.084	1.68
	Cordia sulcata	Cs142	4		0.72	0.92	0.42	0.112	1.91
		Cs185	5		1.20	0.84	0.34	0.106	2.11
	Cyrilla racemiflora	Cr106	6		0.26	0.23	0.12	0.035	0.83
	Dacryodes excelsa	De 20	7		0.48	0.46	0.18	0.079	1.29
		De 21	8		0.68	0.36	0.20	0.076	1.21
		De 51	9		0.56	0.52	0.16	0.070	1.20
		De 54	10		0.76	0.44	0.20	0.070	1.37
		De 96	11		0.35	0.36	0.14	0.065	1.06
		De107	12		0.34	0.34	0.20	0.066	1.01
	Didymopanax morototoni	Dm 81	13		1.24	0.84	0.32	0.087	1.55
		Dm 82	14		1.08	0.76	0.34	0.070	1.41
	Drypetes glauca	Dg 10	15		1.32	2.40	0.38	0.090	1.92
		Dg 17	16		1.76	1.24	0.36	0.093	1.78
	Eugenia stahlii	Es 5	17		0.48	1.00	0.46	0.040	0.91
		Es 6	18		0.38	1.08	0.42	0.039	0.63
		Es 15	19		0.32	1.44	0.42	0.038	0.78
		Es 36	20		0.68	0.68	0.34	0.036	0.69
	Eugenia stahlii	Es 15	21		I.S	I.S	I.S	I.S	0.61

Type of material	Name of Species	Letter code and tree numbers	Lab. code	Na	K	Ca	Mg	P	N
Leaves									
	Miconia prasina	Mp 27	1		0.56	2.08	0.01	0.065	1.70
		Mp 34	2		0.48	1.84	0.01	0.062	1.60
		Mp 72	3		0.48	1.92	0.02	0.069	1.59
	Miconia tetrandra	Mt 79	4		0.31	2.00	0.01	0.063	1.64
		Mt 88	5		0.56	2.68	0.18	0.054	1.37
	Myrcia berberis	Mb 56	6		0.60	2.84	0.50	0.053	1.42
	Myrcia splendens	Ms 8	7		0.48	1.00	0.46	0.059	1.10
		Ms 73	8		0.48	0.76	0.46	0.058	1.32
	Neorudolphia volublis	Nv 69	9		I.S	I.S	I.S	I.S	2.97
	Ocotea leucoxylon	Ol 41	10		1.64	1.00	0.24	0.086	2.45
		Ol 61	11		1.36	0.84	0.30	0.087	2.47
		Ol 86	12		1.26	0.60	0.20	0.095	2.66
	Ocotea portoricensis	Op 104	13		0.72	1.00	0.26	0.074	1.68
	Ocotea spathulata	Os 100	14		0.68	0.29	0.18	0.068	1.51
	Ormosia krugii	Ok 51	15		0.64	0.34	0.14	0.088	2.35
	Palicourea riparia	Pr 4	16		1.56	1.00	0.40	0.079	2.49
		Pr 25	17		1.32	1.24	0.34	0.090	2.31
		Pr 26	18		1.40	1.24	0.52	0.083	2.47
		Pr 52	19		1.68	1.32	0.44	0.094	2.22
		Pr 55	20		1.52	1.44	0.44	0.090	2.67
		Pr 59	21		1.64	0.29	0.38	0.075	2.38
		Pr 77	22		1.36	1.32	0.56	0.081	2.58
		Pr 92	23		1.52	0.92	0.58	0.102	3.37
	Psychotria berteriana	Pb 29	1	0.48	2.36	1.60	0.62	0.110	2.81
		Pb 39	2	0.71	1.92	1.52	0.80	0.085	1.99
		Pb 44	3	0.34	1.84	1.52	0.80	0.114	2.85

Type of material	Name of Species	Letter code and tree number	Lab. code	Na	K	Ca	Mg	P	N
Leaves	Philodendron krebsii	Fk 108	4	0.56	2.96	2.92	0.38	0.117	1.77
	Buchenavia capitata	Bc 18	5	0.02	0.72	0.84	0.24	0.093	1.80
	Rourea glabra	Rg 12	6	0.13	0.76	0.84	0.58	0.052	1.44
		Rg 31	7	0.13	0.56	1.16	0.50	0.049	1.11
		Rg 31	8	0.13	0.60	1.08	0.48	0.046	1.11
		Rg 97	9	0.09	0.80	1.00	0.26	0.050	1.13
	Skelegelia portoricensis	Sp 101	10	0.36	2.12	1.24	0.76	0.123	0.82
	Sloanea berteriana	Sb 11	11	0.06	0.72	1.16	0.20	0.078	1.30
		Sb 13	12	0.03	0.60	0.92	0.22	0.066	1.37
	Sloanea berteriana	Sb 11	13	I.S	I.S	I.S	I.S	I.S	0.98
		Sb 13	14	0.08	0.72	0.23	0.10	0.066	1.29
		Sb 13	15	0.04	0.56	0.84	0.22	0.066	1.38
	Ixorea ferrea	If 60	16	0.23	1.16	1.52	0.30	0.046	1.32
	Tabebuia heterophylla	Th 16	17	0.21	1.08	0.58	0.28	0.080	1.35
		Th 40	18	0.02	1.68	0.42	0.32	0.107	1.43
		Th 62	19	0.06	1.64	0.33	0.26	0.100	1.20
	Tetragastris balsamifera	Tb 75	20	0.15	1.00	0.92	0.22	0.066	1.28

Note: The code used in processing and reporting these data has letters for latin names from the 1964 report page 42. The numbers of these trees are not in the same series as those on living trees still in the area, some of which bear the same number.