CEER - T-089

TROPICAL RAIN FOREST CYCLING AND TRANSPORT PROGRAM

PHASE I PROGRESS REPORT

TERRESTRIAL ECOLOGY DIVISION
CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO
SAN JUAN, PUERTO RICO

JANUARY 1981

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UNIVERSITY OF PUERTO RICO — U.S. DEPARTMENT OF ENERGY

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1.0 EXECUTIVE SUMMARY

This program was designed to fulfill the clear need for a comprehensive understanding of major cycling and transport processes in rain forest ecosystems so that the ecological consequences of potential energy development alternatives can be predicted. As a result of reduced DOE funding for fiscal year 1981, the original program plan (June, 1980) has been modified. The basic approach has not been altered, but some tasks have been reduced in scope where the least damage would be done by substituting information available from published sources.

Phase I of the two-phase multiyear program is underway and most tasks are on schedule. The first wet season sampling surveys have been completed and substantial progress has been made toward achieving phase I goals. Unexpected results (e.g. the discovery that one lizard species which is uncommon near the ground is extremely abundant in the forest canopy) and elucidation of the food web by gut content analyses and feeding observations have already demonstrated the value of the phased approach. The integration of these results with the massive body of biological information from the rain forest at El Verde (Odum and Pigeon, 1970) will provide the needed departure point for investigating energy related disturbances in this important ecosystem.

Four randomly selected plots (1 ha. each) were surveyed and marked in July, 1980. A 300 mn transect line was subsequently placed diagonally through each plot. A single 300 x 300 m grid (staked at 30 m intervals) for use in vertebrate surveys has recently been added.

Calorimetric measurements have been made on selected animal species. Additional species will be sampled, and vegetation samples will be processed as phase I is continued. Sulfur content has been calculated for two common species of lizards and estimates for other species are underway. Other mineral analyses will be added in turn.

A new task has been added with the objective of quantifying carbon export from the forested Rio Espiritu Santo watershed. Data from this study can be correlated with rainfall and decomposition information ob-

tained in the study area (which lies entirely within the watershed) to extend our knowledge of this potentially important process.

Vegetation studies are behind schedule as the result of an untimely staff vacancy which developed at the beginning of the field season. Research is now underway on phenology, litterfall, and plot characterization. Decomposition studies are now scheduled to begin during the forthcoming dry season (January-April, 1981). Plot characterization and interplot comparisons are considered important in phase I so that they may serve as an accurate basis for phase II investigations.

Faunal studies have been emphasized during phase I because of the need for comprehensive data on the interrelationships among major animal groups in rain forest communities. Initial investigations have already provided significant new insights on abundance, distribution, and feeding relationships among species, and further discoveries are expected when studies are continued into the next field season.

The role of phytophagous invertebrates is central to food web analyses. Their use as prey for larger species is partially known from the literature and from initial gut contents studies, but research on their role as primary consumers have been delayed pending the hiring of an invertebrate ecologist. The position has recently been filled and studies are scheduled to begin in February, 1981.

Vertebrate studies are on schedule, with the exception of mammal surveys which were delayed because of a potential rabies problem. Key species have already been identified in each class. The tree frog Eleutherodactylus coqui is easily the most abundant amphibian. Three lizard species (Anolis gundlachi, A. evermanni, and A. stratulus) are the most abundant reptiles. Although the bananaquit (Coereba flaveola) is the most abundant bird species, other larger species such as the red-necked pigeon (Columba squamosa) may be key species in terms of biomass. Among mammals the black rat (Rattus rattus) appears to be the most abundant terrestrial form. Bat species have been collected but studies of their population density are difficult and have not been attempted in phase I.

Progress at this point in phase I studied has been substantial. Calorimetric and chemical analyses of key species are underway and carbon export research has been initiated. Vegetation studies, although started late, will produce the required data by the end of phase I field studies. Several key animal species have been identified, including one anole which was formerly thought to be uncommon in the forest. The importance of vertical studies for all faunal groups has been demonstrated and will be emphasized as research continues. Initial food studies have produced new information on the feeding relationships and identified some of the major pathways of movement for energy and mineral through the foodweb. Integration of information from separate tasks is inappropriate at this point, but the preliminary results suggest that new insights into animal community organization in tropical rain forests are likely to result from phase I studies.

2.0 INTRODUCTION

The accelerated development of traditional and unconventional energy resources is impacting ecosystems throughout the world. The nature and extent of these impacts is related not only to the type of energy development (e.g. fossil fuel, nuclear, biomass, solar, etc.), but also to the prevailing environmental conditions (e.g. annual temperature fluctuations, rainfall elevation). Therefore information on temperate ecosystems has limited application in tropical regions. Potential impacts on temperate zone ecosystems are relatively well known but tropical ecosystems, particularly rain forests, are understood in far less detail. Their importance in the world carbon cycle and regional significance have been identified and inputs and outputs have been calculated, but the structural complexity and functional interrelationships of species (e.g. food webs, mineral cycles) are poorly known.

We are therefore investigating cycling and transport processes within a relatively simple moist tropical (tabonuco) forest. Initial studies are being conducted in the rain forest near the El Verde Field Station. Once a comprehensive overview has been obtained through integration of the results of Phase I field studies with the substantial body of published information on the same study area, in depth studies involving experimental manipulations will be undertaken.

Because the original program plan (June, 1980) was formulated prior to the reduction in funding for fiscal year 1981 the program has been adjusted accordingly. Basic objectives and overall design have not been altered. Some tasks elements have been eliminated, and some sampling reduced to a single season where it was felt that sufficient supporting information could be obtained from existing literature. Other task elements have been added on the basis of observations and preliminary data analyses obtained during the first seasonal sampling period.

This document presents the modified program design and progress as of November 30, 1980 on the Phase I studies. Detailed methods are included so that this report can also serve as a reference guide for future studies. Extensive analyses of preliminary data are not possible at this point. Substantial, and in some cases unexpected results have been obtained which have confirmed the value of this phased approach. Results are presented and discussed by task in this report, but because of the imcomplete nature of data sets no attempt has been made to integrate data from different tasks.

3.0 PROGRAM OVERVIEW

It is necessary to understand the major features of ecosystem structure and function and their response to exogenous environmental variables in order to predict the effects of expanding energy technology on tropical ecosystems. Current knowledge of the source-sink role of tropical rain forest biota and the factors which regulate this role is insuficient to fortell the impact of energy development on the mobilization and release of critical elements or the ecosystems capacity to assimilate elemental imputs. By investigating cycling and transport in a well studied and relatively simple tropical forest ecosystem, we intend to identify key pathways and major reservoirs of minerals and energy so that relevant hypotheses can be developed and tested concerning potential energy development impacts.

Cycling and transport processes are being investigated in the tropical moist (tabonuco) forest at El Verde by conducting a two phased program so that a firm data base can be established and subsequent experimental manipulations can be undertaken. The long history of environmental research in the Luquillo Mountains and the existence of the El Verde Field Station in this forest provide a unique opportunity for this type of research. In the proposed program we are building on previous work at El Verde to examine the food web structure and identify important factors involved in faunal components of cycling and transport processes, a concept which has received little attention in temperate ecosystems and even less in the tropics.

Phase I studies are focused on obtaining missing information on the forest ecosystem and integrating these data with published information to construct a meaningful model of mineral and energy storage and movement. Faunal components are emphasized in this phase because of the lack of comprehensive food web data for tropical forests, and because of the wealth of relevant vegetation data for the study area. The objectives of phase I studies are:

1. to identify the major reservoirs and pathways of minerals and energy in the forest, and

2. to develop hypotheses concerning the potential effects of energy development related disturbances (e.g. inputs of sulfur, carbon, etc.) on cycling and transport.

Each task and subtask will provide information directed toward these goals. The mineral inventory will provide information on the mineral and energy value of each major class of items (fruit, leaves, feces, individual animals, etc.) in each ecosystem compartment. Faunal studies will quantify the number of such items in each compartment and the rate of movement of these items between compartments. In addition to studies characterizing study plots, the vegetation work will provide a basis to compare the magnitude of elemental flow through compartments with direct movement of primary production to the decomposer compartment via leaf and fruit fall and litter decomposition.

We are attempting to achieve the above-stated objectives by the following steps:

1) delineation of trophic structure food webs and food web segments,
2) identification of dominant species in each food web or food web segment,
3) quantification of vertical, horizontal and temporal pattern of the distribution of identifiable functional units (species, trophic groups, food web segments, etc.) of the forest ecosystem,
4) quantification of the distribution of key elements among major functional units of the system taking into account spatial and temporal considerations,
5) development of a refined forest ecosystem model which will permit simulation of cycling and transport processes, and
6) generation of hypotheses concerning the potential impacts of energy development which are both relevant to tropical forest ecosystems and testable in phase II.

An important result of the proposed study will be a detailed food web in which major aspects of the distribution and transfer of minerals are known. Evaluation of these data is likely to produce useful insights on the relationship of food web complexity to species diversity, and about the influence of rainfall, humidity, soil type, nutrient pools, dominant consumers, and food web structure on the overall structure of ecosystems. This information will provide an important conceptual basis for inferring the key points at which perturbations due to energy development are most likely to disrupt natural systems.

Phase II will primarily involve the testing of hypotheses, although some phase I studies (e.g. population turnover rates) will be continued into this phase. Hypothesis testing may take a variety of forms. Direct manipulation of the forest by methods such as the addition of particular elements may be undertaken, as permitted by the U.S. Forest Service. Studies of existing plantations of various ages and managed forest areas may be conducted to gather comparative data on cycling and transport characteristics, including food web complexity. The exact nature and extent of these studies will depend largely on information acquired and synthesized in phase I and are not considered in detail at this time, although several questions relating to the impacts of energy development on tropical forest can already be posed.

Several hypotheses can be generated which involve comparisons between native tropical hardwood (tabonuco) forest and plantations (including those which are managed for energy production). Specifically, one can hypothesize that in the native hardwood forest:

1. productivity is higher,
2. consumer biomass is greater,
3. insect pests are less abundant,
4. food web structure is more complex,
5. nutrient cycling is more rapid, and
6. the system is more resilient to exogenous disturbances

than in plantations on the same soil types and under the same rainfall regimes. The hypotheses selected for testing in phase II will be based on information acquired in phase I and on a realistic evaluation of potential energy related impacts.

4.0 PHASE I METHODS

A compartmentalized ecosystem model (Figure 1) is being used as a framework for coordinating the various task studies. Work will focus on those ecosystem compartments above primary producer in the food chain for the following reasons: (1) the importance of higher trophic level in mineral transport has already been suggested for some forests (Weir, 1969), but the role of fauna in moving energy and nutrients among compartments of terrestrial ecosystems has been largely neglected (Sturges et. al., 1974; Burton and Likens, 1975), and (2) primary production and elemental cycles have already been studied in the moist tropical forest (Odum and Pigeon,1970). For these reasons only a partial measurement of mineral transport in and out of the forest ecosystems will be begun in phase I of the project, and values needed for the current study will be taken from the literature and/or from the work of visiting and collaborating scientists.

4.1 Sampling Design

The study area (Figure 2) was selected because of its long history of continuous research, beginning with the rain forest gamma radiation studies (Odum & Pigeon, 1970), and its proximity to the established facilities at the El Verde Station. Other factors which were evaluated in the study area delineation process were the relationship to U.S. Forest Service research areas and the amount of existing disturbance from previous studies.

The overall design is stratified random. Four sampling locations (points) were randomly selected within the study area so that subsequent statistically valid analyses can be performed (Green, 1979). Sampling points were selected using a grid technique (Phillips, 1959). The following criteria were used in the selection of random plots:

- potential confounding factors (e.g. roads, perennial streams, previous destructive sampling) are not present within 50 m of a sampling point.

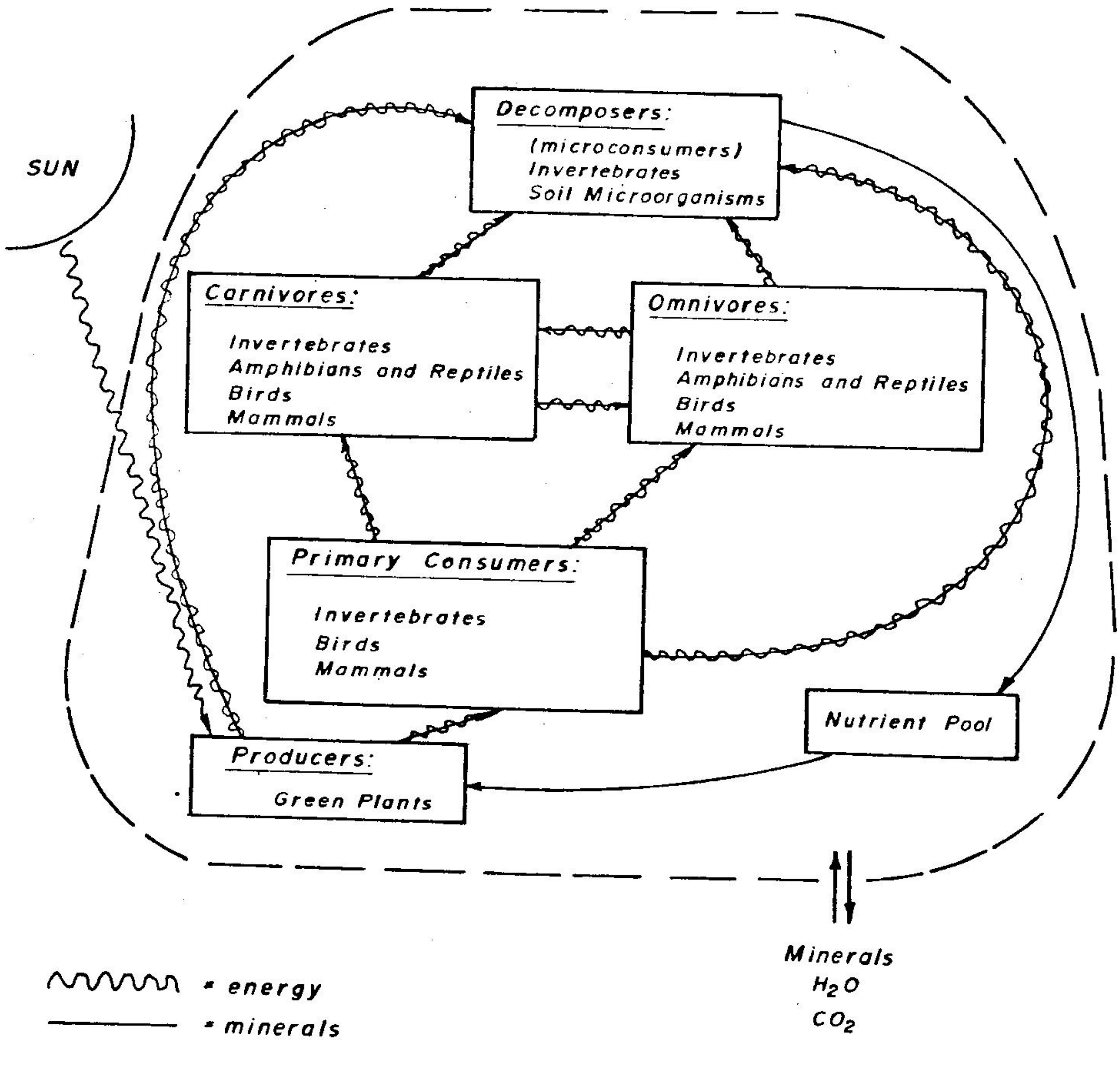


Figure I. Generalized Ecosystem Model

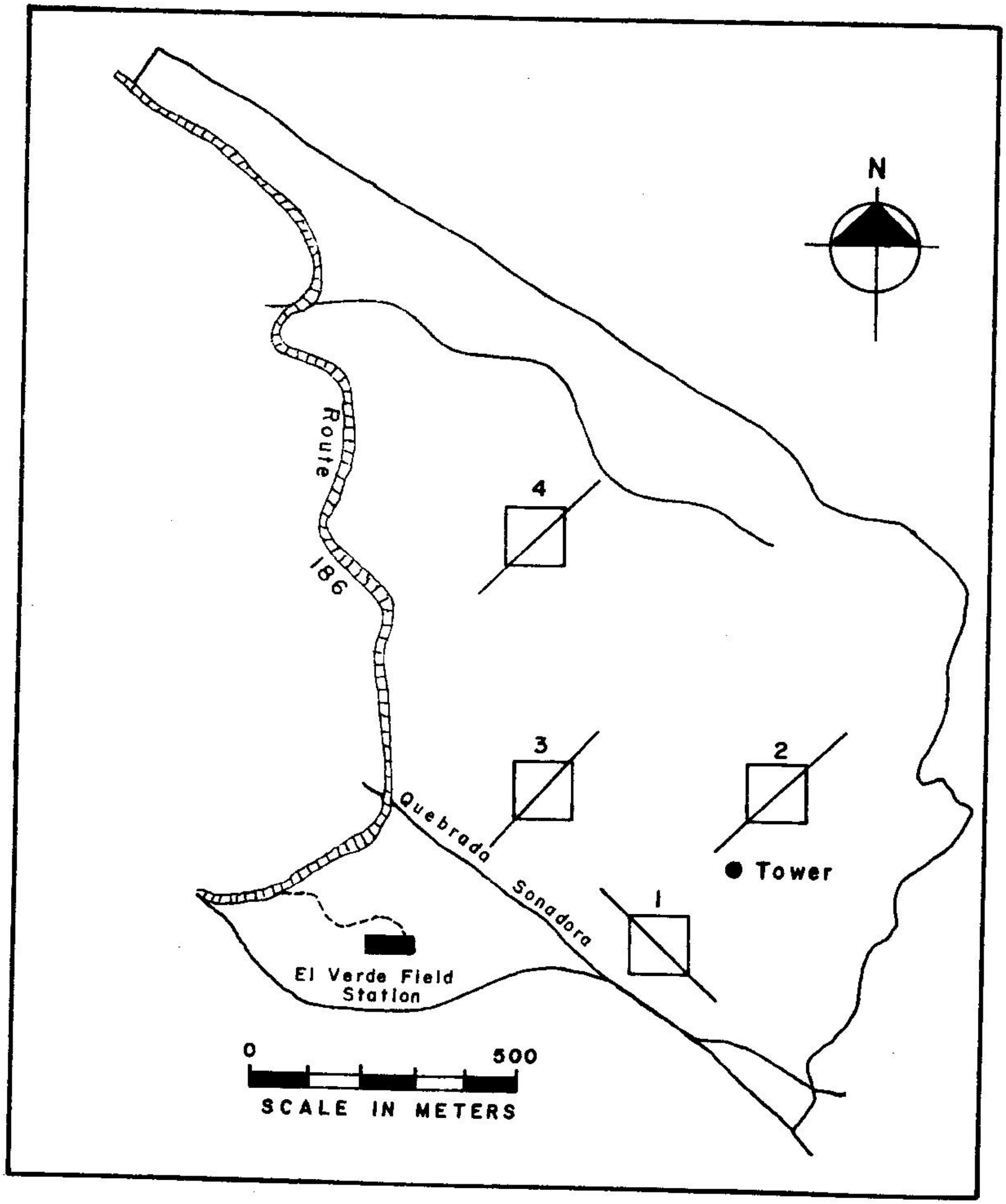


Figure 2. Rain Forest Study Area

- sample points will be no closer than 200 m to each other so that sampling overlap can be avoided, and
- reasonable access is possible.

The size of the area to be sampled at each randomly chosen point will vary according to the discipline being studied. A one hectare plot with boundaries marked at 10 m intervals has been established at each sampling point. Plot and plotless methods, transects, and detailed inventory procedures are used in phase I investigations. Studies focus on sampling points, but include other portions of the defined study area.

Most sampling is being conducted during a minimum of two seasons. Most surveys will occur during the wet and dry seasons, but additional sampling is required for some tasks (e.g. breeding bird surveys). The timing of field surveys is being coordinated to avoid sampling interference yet maintaining a close temporal correspondence among field studies.

4.2 Task Methods

Each task is described as a separate entity within the overall phase I sampling design because of the variation in pertinent information already available for different disciplines. The tasks are of varying durations, but all should be completed within 12 to 14 months (see Schedule section). Following the initial phase, the program will be evaluated and some studies continued with modifications (e.g. growth and population turnover of key species). Although the data acquired should be of immediate value, they are also intended to provide a basis for long term in depth studies continued under phase II of the cycling and transport program. The options will be better defined as phase I approaches completion.

Objectives, detailed methods and results are presented for each task and the significance discussed. Conclusions and integrated data presentation are not included because of the preliminary nature of the information obtained for some of the tasks.

4.2.1 Physical Phenomena

Basic information on physical aspects of the environment is necessary in order to interpret biological observations and to provide baseline data for phase II studies. Specific objectives are:

- to collect pertinent weather data to be used in evaluating information collected from other tasks
- to document seasonal and other temporal changes within the study area
- to record stream flow from the Sonadora watershed in order to evaluate transport from the study area

Materials

- rain gages (at El Verde Station and tower)
- thermometers and hygrothermographs (at El Verde Station and four levels at the tower)
- wind speed and direction recorder (tower only)
- stream gaging station (at suspension bridges on Quebrada Sonadora within the program study area)

4.2.2 Mineral Inventory and Energy Studies

The fixation of energy from the sun in plant materials is the ultimate driving force for cycling and transport processes in tropical rain forests. Movement of key minerals and energy through the systems is being investigated by identifying the major pathways and quantifying movement between major compartments (Figure 1). Because of the important role of tropical forests in carbon cycling, a new task has been added which addresses the role of rainfall events in carbon export from the watershed which includes the program study area.

4.2.2.1 Mineral Inventory

Sulfur: Material to be analyzed for sulfur is mixed 4:1 with benzoic acid, compressed and oxidized by burning in a combustion bomb under 28 atmospheres of oxygen pressure. The contents of the bomb are subsequently depressurized and rinsed through a coarse, rapid filter with four

50 ml. portions of doubly distilled water. The volume is reduced to 100 mls. by evaporation on a hot plate and standard gravimetric techniques are them used to analyze for sulfate.

Other Methods

All other analyses are carried out according to procedures specified in APHA-AWWWA-WPCF "Standard Methods for the Examination of Water and Wastewater", nitrate using the standard amalgamated cadmium reduction followed by diazo coupling of sulfanilamide and N-(1 Naphthyl-ethylenediamine). The intensity of color is read with a spectrophotometer.

Organic and ammonia nitrogen are measured using standard Kjeldahl analysis with titration of indicator boric acid solution trap following digestion and distillation.

Phosphate is measured using vanado molybolate heteropoly acid color development and subsequent readout using a spectrophotometer.

Collections associated with the sediment graph/carbon export correlation are also being used for analysis of export of nitrate, phosphate and organic nitrogen. The possibility of sulfur/sulfate analysis will also be addressed in the coming months.

Inasmuch as wet weight/dry weight and ash weight analysis of secondary consumers such as eleutherodactylid and anolid species in the forest are not well described, and since ash-free dry weight is important for the description of the calorimetry of these animals, data on ash weight, wet and dry weight are presently being accumulated. The animal's tissue is also burned under controlled conditions (bomb calorimeter) in order to determine the energy storage in the animal compartments of the forest. The residues after burning were rinsed, filtered and analyzed for sulfur (SO_4^-).

4.2.2.2 Calorimetry

Calorimetric measurements are being made on organisms which are known or suspected of being major components of the rain forest ecosystem.

Dried samples are mixed with benzoic acid burn adjuvant and an accurately weighed sample of approximately 1 gram is burned in the oxygen bomb at 28 atmospheres pressure following moistening with 2 drops of a 1% solution of triton X-100. These conditions control the burn. Standards of pure benzoic acid (6,318 cal./gm) are run periodically as a calibration of the calorimeter. Temperature differences are read to the nearest thousandth of a degree. All measurements are corrected for unburned fuse wire and a pre-burn oxygen purge is used to eliminate atmospheric nitrogen from the bomb.

4.2.2.3 Carbon Transport

This task was added subsequent to the development of the original program plan. Carbon transport from the forested upper Rio Espiritu Santo watershed is being quantified. Analysis is based upon a model which gages sediment export from flow-monitored streams. The Cara del Indio hydrological gaging station on Rte. 966 is an appropriate site for collections of sediments for analysis of the sediment graph during sediment exporting events. The hypotheses developed are based on the following considerations:

1. Sediment may or may not be associated with the bulk of the carbon exported via the drainage system.
2. Base flow conditions which might be responsible for some inorganic (dissolved) carbon export should not be very significant.
3. Long term storage cycles of carbon ($>$ 1000 years) may be responsible for more CO_2 atmospheric buffering than is presently thought.

Our observations consist of surface and bottom water collection during base flow and high water conditions and analysis of the water with respect to inorganic and organic carbon.

Organic carbon is measured using a standard sealed vial oxidation technique (c.f. Oceanography International Operating Manual) employing potassium persulfate as the strong oxidant. The vials are scored and broken after the neck has been sealed within a gas carrying system. A purge of nitrogen gas acts as a carrier to bring the liberated carbon dioxide (CO_2) through the infrared sensing system of an Oceanography International total organic carbon analyzer. The detection response is integrated with respect to time electronically and the relative integrated peak area is related to calibration areas curves. Substances used for calibration of the response curve areas include sodium carbonate primary standard and potassium acid phosphate primary standard.

Inorganic carbon is measured by injecting a known volume of sample into a 2M solution of phosphoric acid placed within the nitrogen purge system of the Oceanography International total carbon analyzer. These acidic conditions are sufficient to convert all carbonic acid, carbonate and bicarbonate ion to free carbon dioxide which is purged with the nitrogen system described above.

4.2.3 Vegetation Studies

Considerable information has been accumulated on the vegetation of the Luquillo Mountains, including the rain forest at El Verde (Odum and Pigeon, 1970). Phase I studies are designed to fill important data gaps (e.g. variability in litterfall, decomposition rates, etc.) which have been identified, and will provide baseline data for experimental studies which are planned for phase II.

4.2.3.1 Plot Characterization

Several types of information are needed in order to provide a basis for interpreting faunal data and for designing phase II investigations. Initial characterization techniques are described below.

Structural Analysis

- All the vegetation 10 cm dbh or greater will identified, tagged with species name, dbh, measured, and height determined.
- Between plot comparisons will then be made of:

  Species composition,
  Species importance,

Biomass, and standing crop of elements in biomass (Ovington & Olson, 1970).

Topography

Information will be gathered on slope and aspect in each site to add information regarding between-plot variation.

Loose Litter

- Variations in the forest floor litter components among plots will be determined by collecting samples at random in each plot each season. The number and size of the samples will be based on plot heterogeneity and prior sampling surveys.
- The material collected will be separated into the wood and miscellaneous components, dried at 70°C for 72 hours, and weighed.

Minimal Area

Pilot studies were conducted within the study area in April, 1980 which indicated that 1 hectare was adequate for phase I vegetation studies. Further work is not planned in this phase.

4.2.3.2 Phenology

Objectives:

- To look for temporal differences in species flowering and fruiting patterns within and between plots
- To determine importance of species contribution to flower and fruit fall

Methods and Materials:

- See litterfall for sampling location information
- Flowers and fruits will be separated monthly by species for each basket, counted, dried at 70°C for 72 hrs. and weighed.
- Phenological studies will be limited to the flowers and fruit contribution to litterfall as determined by basket collection in each plot. Prior extensive phenological studies in P.R. (Estrada, 1970; Bannister,

1970, Nevling, 1971) indicate that detailed additional studies would be repititious and of low priority at this time.

4.2.3.3 Litterfall

Objectives:

- to determine seasonal pattern of litterfall as a whole and for individual species
- to detect differences between sites for total and species litterfall

Methods and Materials:

- Twenty 1m^2 galvanized hardware cloth baskets lined with 1 mm mesh fiberglass screen were placed in each of the 4 plots.
- The locations of 4 litterfall transects were randomly selected at each site with 10 m intervals between potential transect lines. Five baskets were randomly located along each transect (Figure 3).
- Each basket was elevated at least 10 cm from the forest floor (30 cm where possible) and leveled.
- Collections of the litterfall are made bimonthly. The mid-month collection is separated by basket into leaves, flowers, fruits, wood and miscellaneous items.
- The collections at the end of the month are air dried; separated by species into leaves, flowers, fruits; and sorted by basket into wood and miscellaneous items.
- Each component at each collection is counted, dried at 70°C for 72 hours and weighed.
- Wet season-dry season samples will be processed by species by plot (some species by transect) for caloric and mineral content.

4.2.3.4 Leaf Decomposition

Objectives:

- To determine the seasonal decomposition of freshly fallen leaves
- To compare the between plot rates of leaf decomposition

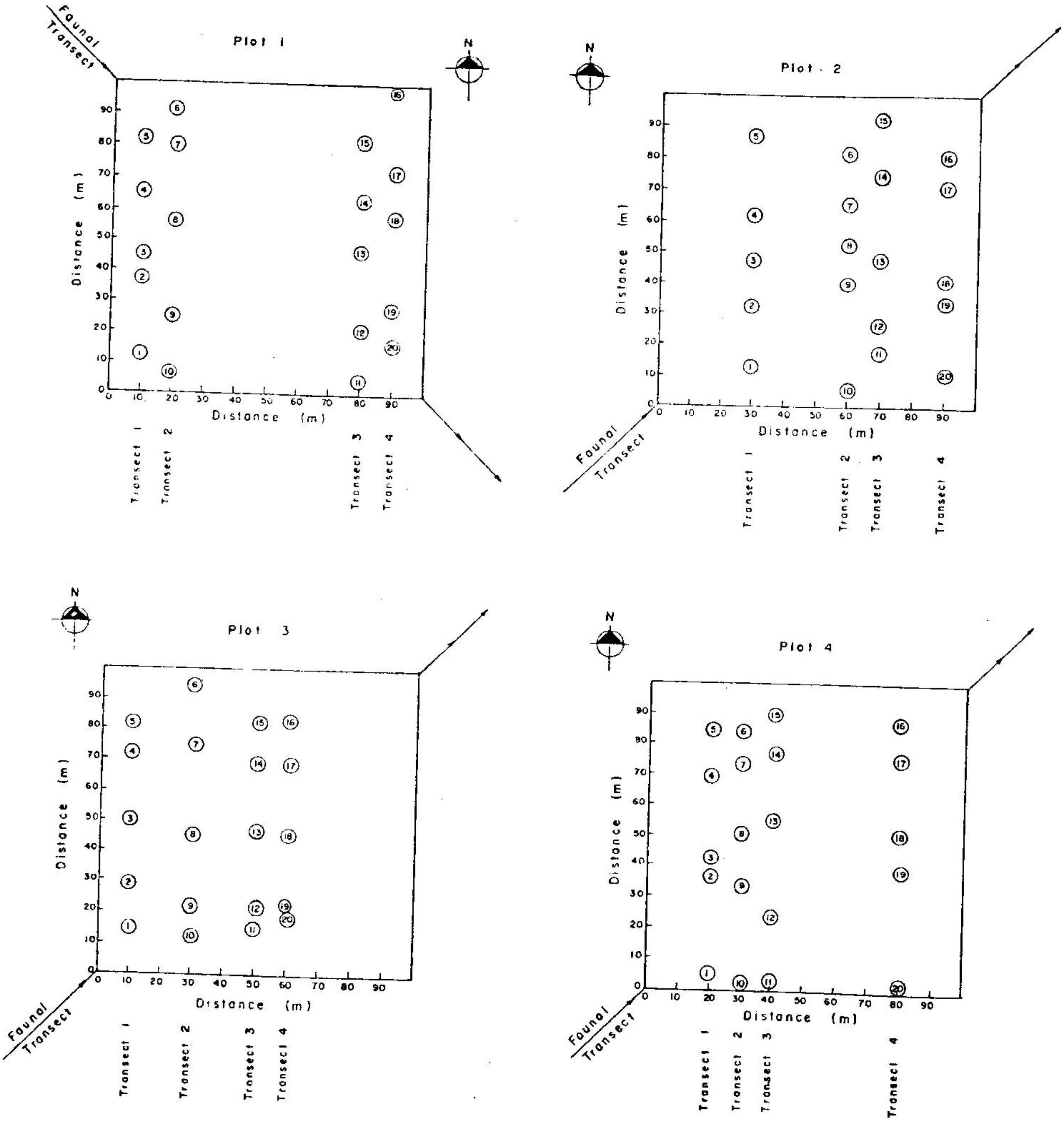


Figure 3. Randomly Selected Vegetation Sampling Locations Within Study Plot.

- To evaluate the effect of species composition of the decomposition rate
- To determine the change in caloric value and mineral content over time and between major seasons.

Methods and Materials:

- Freshly fallen leaves will be collected seasonally from each of the four study plots in order to represent species composition, approximate quantity, and the chemical composition of the leaves in each plot.
- The leaves will be air dried overnight to remove surface moisture. Twenty grams of air dried leaves will be placed in each 25x40 cm fiberglass screen-bag (1 mm mesh) for a total of 170 bags/site.
- Eighty bags containing leaves from plot 1 will be placed in plot 1, four near each of the 20 litter baskets. Eighty bags containing leaves from plot 1 will be placed in plot X selected for site homogeneity. Ten bags will be reserved for fresh weight-dry weight converstion.
- The above will be conducted for each of the four plots, thereby detecting any variation in the decomposition rates between plots. By randomly placing decomposition bags from each of the 4 plots in one homogeneous area (plot X), any differences in the decomposition rates between the plots due to species composition will be determined.
- Ten bags will be collected at random from each site plus 10 bags representing each site from plot X (40 bags total each collection) at 7, 14, 20 days; 2,4,8,16 months. The remaining bags will be considered a field reserve in case of unpredictable bags destruction.
- Caloric values and mineral content will be determined on 3 of the bags from each plot at each collection to determine temporal variations.

4.2.4 Faunal Studies

The roles of animals in ecosystem structure and function can be effective evaluated by combining energy flow and nutrient cycling studies. Recent work in temperate forest ecosystems has provided valuable information on the roles of animal populations as nutrient "sinks" and as agents of nutrient transport (Weir, 1969; Sturges et. al., 1974; Burton and Likens, 1975).

Because of their potentially high turnover rates at relatively high ambient temperatures, underestimating the importance of organisms with short life spans and low standing crops in cycling and transport processes is even more likely in tropical systems than in temperate systems. The proposed phase I faunal studies are designed to investigate that possibility in the tropical forest ecosystem at El Verde.

The major faunal sampling effort is aimed at obtaining information on the food habits and general abundance of animals. From these data emphasizing top carnivores and herbivores a comprehensive food web will be constructed. Initial food web analyses will attempt to define major pathways rather than focus on parallel food subwebs (Paine, 1966; Gilbert, 1980) which may or may not be important structural units in this insular tropical rain forest.

Studies will focus on those intermediate consumers serving as principal diet items for higher order carnivores. Attempts will be made to estimate population turnover rates for key (i.e. abundant, frequently eaten or large) consumers. To some degree, intermediate consumer roles and rates will have to be estimated in a pooled fashion from differences between rates of primary productivity litter fall and decomposition and consumption rates of top carnivores.

The faunal studies will phase from highly diversified qualitative collection through more selective sampling aimed at relative abundance to highly specialized quantitative sampling, aimed at key species. Relative abundance and absolute abundance data will be combined to refine portions of the food web. Turover estimates plus metabolic data will be used to quantify flows. Because of expected seasonality some types of sampling will be continued throughout the entire period of study. However, with each successive sampling period,more effort will be placed on relative and absolute abundance estimation for key species and species groups rather than upon the identification of new species.

In time, more detailed paths will be able to be delineated and quantified and it will become possible to test whether additional refinement is needed to predict the influence of man-made changes upon processing by these ecosystems. More specific descriptions of research tasks and methods follow for the major faunal groups.

4.2.4.1 Invertebrates

The invertebrates fauna influences cycling and transport processes in the rain forest ecosystem in three major ways. First, by grazing on photosynthetic and reproductive structures of plants (e.g. phytophagous insects) they affect forest primary productivity and alter plant species composition and diversity (Janzen, 1970, 1973; Mattson and Addy, 1975). Secondly, as decomposers and detritus feeders in the soil and litter they are responsible for breaking down dead organic matter, making nutrients available to the plant community. This latter function is of great importance to the plants of a tropical forest, which, due to leaching and soils low in nutrient concentrations, must incorporate nutrients at a rapid rate. Thirdly, invertebrates play a role of unknown magnitude as predators, certainly influencing and possibly controlling the density and species composition of selected primary consumers (Hairston et. al., 1960).

In view of these characteristics of the invertebrate fauna, the importance of their role in the flow of energy and cycling of nutrients in the tropical rain forest becomes evident. Unfortunately, few studies have contributed to the understanding of the different ways in which invertebrates influence the flow of energy and nutrient cycling in tropical terrestrial ecosystems. The majority of invertebrate studies in the tropics have been limited to crude estimates of absolute or seasonal abundance and some biomass determinations.

Studies of the dynamics of invertebrate populations have historically emphasized economic pest species, resulting in models of populations that are not general enough for prediction of randomly selected species (Clark, et. al., 1967; Gilbert and Singer, 1973). The few detailed studies of invertebrate populations in the tropics, limited to groups of insects such as butterflies of the genera Acraer (Owen, 1971) and Heliconius (Ehrlich and Gilbert, 1973), and euglossine bees (Janzen, 1971), have shown that for these species population size remains constant through time but turnover rates are high. If this is true for other tropical forest invertebrates, then because they comprise a large proportion of the faunal biomass, invertebrates must play a major role in tropical ecosystem nutrient cycling and energy flow. It has been demonstrated in temperate forests that invertebrates, in particular phytophagous insects, regulate forest primary productivity (Mattson and Addy, 1975). However, the same has not yet been demonstrated in tropical ecosystems.

Most of the work concerning forest invertebrates in Puerto Rico has been limited to pest species, taxonomic descriptions, and relative abundance and/or food preferences of selected species (Martorell, 1943; De Leõn, 1944; Wolcott, 1940; 1946; 1950; Drewry, 1970). The only studies that have emphasized the role of invertebrates in the rain forest ecosystems were performed during the AEC Radiation Experiment (Odum and Pigeon, 1970) in the tabonuco forest at El Verde. These studies covered the major groups of invertebrates in the tabonuco forest including aquatic communities in bromeliad leaf axils (Macguire, 1970),nematodes in litter and soil (Coleman, 1970), termites (MacMahan, 1970), soil microarthropods (MacMahan & Sollins, 1970) and mosquitoes (Weinbren & Weinbren, 1970). However, these studies were fragmentary and conducted during different seasons and/or years and leave even the basic inventory incomplete.

To attempt to study the role of all invertebrates in ecosystem structure and function and their effect on energy flow and nutrient cycling is impossible due to the magnitude of the task. Additionally the taxonomy, autecology and population dynamics of most invertebrates have not been well studied. For this reason the scope of this study will be limited to phytophagous insects, their principal predators and the soil fauna.

- Phytophagous insects: Phytophagous insects of both low and high strata of the vegetation will be sampled by means of sweep nets special enclosures, malaise traps, light traps and/or a sucking apparatus (De-Vac Sampler). Sampling will be done at each season both day and night. Environmental variables will be recorded during sampling.

The effect of phytophagous insects on energy flow and nutrient cycling will be evaluated in coordination with related vegetation studies. The intensity of grazing on leaves and fruits will be quantified by means of the relationship between leaf area damaged or consumed and leaf area index through time.

- Soil fauna: Approximately 90% of forest primary conductivity goes to decomposers (Bray, 1964; Wiegert, 1970); therefore they will be considered the most important with respect to nutrient cycling and energy transfer. The role of soil fauna will be approached in the same manner as for phytophagous insects.

Because sampling accuracy is of utmost importance in estimating population size, soil litter fauna will be sampled by more than one technique. Sampling techniques will be tailored to the characteristics of the different groups. With the help of expert consultants the best method will be chosen from the literature. These techniques may include soil coring (nematodes), flotation, extraction (Berlese and Tullgren funnels or high gradient cannisters for microarthropods). Direct captures will also be utilized for macroarthropods such as myriapoda. As with the phytophagous insects, dominant species will be identified and future experiments designed to investigate their population dynamics.

The soil and litter fauna will initially be treated as one compartment with only prey species being singled out as they are identified from studies of carnivore food habits. As stated previously,for most samples only information on total numbers or biomass will be secured, However,attempts will be made to determine the relationship at different seasons of the year between numbers of cores (or area sampled) and numbers of taxa recognizable.

4.2.4.2 Amphibians and Reptiles

These poikilothermic vertebrates are conspicuous and abundant components of tropical forests. Considerable data are available on the ecology of some groups (e.g. the genus Anolis), but the kind of information required to determine their importance in cycling and transport through these ecosystems is incompletely known. The basic type of data required are (1) mineral and energy content, (2) status in food web (food habits and predators), (3) biomass, and (4) population turnover rates. Initial studies will focus on acquiring information of the first three types.

Subtask 1. Species Inventory

Objectives:

- to determine the presence and general abundance of species not readily observed by transect methods

Methods and Materials:

- Intensive searches at random and selected locations will be conducted periodically throughout the study area, and random observations will be noted.
- Surface debris and litter will be overturned in order to locate secretive and fossorial species.
- The species, location, and general abundance of each species observed will be recorded.

Subtask 2. Presence and Relative Abundance

Objectives:

- to determine the species composition and relative abundance of amphibian (anuran) species within the study area in order to identify important species and to correlate information collected at study plots with more detailed data collected on coquis within the same general area by Dr. M. Stewart and her colleagues.

Methods and Materials:

- Conduct transect surveys along same lines as bird and lizard surveys.
- Walk each transect on three separate evenings at each major season (wet and dry) and record the species, sex

(where possible), and size class of each individual observed along a 50 x 2m belt transect.

- Record the calls of any individuals which cannot be identified in the field.
- Calculate the relative abundance for each species in each of the four plots.

Subtask 3. Anolis Food Habits

Objective:

- to determine the types of food taken, frequency of occurrence, and percentages of food items for each species.

Methods and Materials:

- Collect a minimum of 30 adults of *Anolis gundlachi* and *A. evermanni* during each major season (wet and dry).
- Skill, weigh, and cool specimens immediately in the field.
- Dissect stomach content out of each specimen and place them in preservative (10% formalin or commercial insect preservative). General references Sexton (1972).
- Identify contents as specifically as possible, noting approximate percentage of total contents for each individual lizard.

Subtask 4. Anolis Population Density

Objectives:

- obtain a minimum population density estimate for common species of *Anolis* in each plot at each season (wet & dry)
- obtain a population index and relative abundance estimate for *Anolis* in each plot.

Methods and Materials:

- A permanent transect 150m in length beginning at the center of the plot and extending diagonally from it along existing bird transect is established in each of the four study plots.
- Each transect is surveyed by slowly walking the marked line on three separate occasions: morning (0700-1000), mid-day (1000-1400) and afternoon (1400-1800) during the wet and dry seasons.
- The species, sex (or size class), and distance from the centerline of the transect is recorded for each individual observed.

- Relative abundances are calculated for each plot, and minimum population densities are calculated according to Frye's strip census formula (Overton, 1971):

$$T = \frac{CA}{2L\bar{h}} t$$

$\bar{h}$: average perpendicular distance between observed animal and transect centerline

C: correction factor for units of measurement

L: transect length

A: area of study site

T: estimated population density

t: number of animals observed on transect

Subtask 5. *Anolis* Population Turnover and Growth Rates

Objective:

- to obtain reliable estimates of population turnover and growth rates for the most abundant species of *Anolis*

Methods and Materials:

- Live capture all sizes of *Anolis* within a designated portion of the overall study area.
- Mark animals individually, weigh, measure, sex (when possible), and release. Repeat at 1-3 month intervals and extend into phase II.

4.2.4.3 Birds

Synthesis of new techniques and knowledge gained from preliminary field work has resulted in some changes in the original work plan, with a view toward increasing the value of the resulting data. Current methodology for the program is described below.

Subtask 1. Population Density

Objective:

- To obtain reliable population estimates for each species in all sites studied and to detect changes in population density throughout the year.

Methods and Materials:

- Grid 9 ha. area that includes one of the sampling plots (Plot 3). Grid lines will be established at 30 m intervals and intersections marked with numbered fiberglass stakes.
- Beginning in February, 1981, use modified spot-map methods, mist netting and systematic observations to determine population density for each species in the 9 ha. site (see Holmes and Sturges 1975).
- In each of four 1 ha. sampling plots, establish a 300 m transect line through opposite corners of the plot. Set up a 150 m net lane bisecting each transect line.
- Visit each site 2 days/month to conduct two transect censuses between 0600-0900 using the method of Emlen (1971). Every third month run four transects in each site between 1500-1800.
- By comparing absolute densities from Plot 3 with data from transect surveys from the same plot, calibrate the transect densities to the number of birds actually occurring. Use transect data to estimate population densities in the other three sites.
- After initial transect counts, sample each site dawn to dusk for five consecutive days with mist nets, marking all birds captured. Calculate trappable population sizes (MacArthur and MacArthur, 1974).

Subtask 2. Feeding Behavior

Objective:

- To accumulate sufficient observations of feeding to test for differences between species, sites, seasons and individuals.

Methods and Materials:

- Observe avian behavior for equivalent periods in each site. Record prey items taken, horizontal coordinates of prey capture, height of prey capture, tree species, type of foraging move, direction and distance of foraging move, substrate attacked, perch diameter, location, time, weather conditions, etc.
- Data will compiled and analyzed in a fashion that will make possible comparisons with foraging data taken by C. and A. Kepler in colorado forest and A. Cruz in pine plantations.

Subtask 3. Diet and Weight

Objective:

- To determine differences in diet and weight between species, sites, seasons and individuals; to describe food webs for each site

Methods and Materials:

- Sacrifice sixty birds of 10 species captured outside study sites, identify stomach contents and freeze for bomb calorimetry.
- In conjunction with the banding studies in Plot 3, use ground and canopy mist nets to capture as many individuals as possible in this plot. Also do occasional mist-netting around the boundaries of the other three plots.
- Weigh, measure and mark each individual capture.
- Sample stomach contents of each individual with antimony potassium tartarate emetic.
- Identify stomach contents to the lowest taxonomic group possible.
- Construct partial food web for each site using data collected and literature sources.
- Calculate uptake of minerals using feeding rate and bomb calorimetry data.

Subtask 4. Materials Discharge

Objective:

- to obtain reliable estimates of the amount of fecal and regurgitated material produced/individual of each species per unit time

Methods and Materials:

- Place mist-netted birds in holding cages for 1) one hour during the day and 2) overnight.
- Collect, dry and weigh defecated and regurgitated material.
- Determine average weight of feces and regurgitated material.
- Bomb fecal and regurgitated material to determine mineral content.
- Using observed rates of defecation in the wild and in bird caged overnight, calculate amount of material returned to environment/individual/unit time.

- Test for differences between individuals, species and sites.

Subtask 5. Mineral Content

Objective:

- To obtain reliable estimations of the mineral content per unit weight of 1) whole stomach contents and individual food items, 2) body tissue, 3) feathers and 4) feces and regurgitated material.

Methods and Materials:

- Capture and sacrifice sixty birds of ten different species.
- Remove stomach contents, identify and count, dry separately. Remove and combine fecal material from each species and dry.
- Remove feathers, and homogenize and dry feathers and body tissue separately.
- Determine important food items for each species and collect, homogenize and dry samples of each item.
- Bomb and analyze residue of samples in the following numbers: body tissue, up to 6/species or until low individual variation is established (minimum 10, maximum 60); feathers, same as body tissue; stomach contents, 6/species (total 60); fecal material, 2/species (total 20); food items, up to 50. Grand total = 150-250 samples.
- Calculate per item or per event transfer of minerals.

4.2.4.4 Mammals

The role of mammals in the rain forest ecosystems of Puerto Rico is of particular interest because of the low species richness and because the larger species (e.g. black rat and Indian mongoose) have been introduced by man. Studies of this group will be limited in scope, but basic information is needed prior to implementation of experimental investigations which are planned for phase II.

Objective:

- to determine the presence and general abundance of species within the study

Methods and Materials:

- Twenty Sherman line traps (3x3x9 in) are placed in two lines of 10 traps each at 15m intervals between lines and traps and checked each day for a minimum of three consecutive days. The traps are checked and rebaited (as necessary) daily. Lines were surveyed during mid-November, 1980 and will be surveyed again during the 1981 dry season.
- Larger terrestrial mammals are sampled using Tomahawk line traps (6x6x24 in) deployed in a 5x5 trap grid (Nellis, personal communication) with traps spaced at 30m intervals. Traps are checked and rebaited daily for a minimum of three consecutive days.
- Bats, the only native mammals presently known to inhabit the study area, are surveyed using horizontal and vertical mist nets erected in selected locations within the study area at intermittent time intervals throughout each major season.

5.0 RESULTS AND DISCUSSION

Initial surveys have produced substantial, and in some cases unexpected results. Because these data are preliminary, integrative analyses are not possible at this time. Results are herein reported and discussed by task.

5.1 Physical Phenomena

Daily rainfall and continuous records of relative humidity and temperature fluctuations have been collected at the El Verde Field Station since the radiation studies in the rain forest during the mid-1960's. The tower station was established in July, 1980 and will be maintained throughout the program field studies. Prior to the implementation of phase II studies a wind (velocity & direction) gage, rainfall event recorder and stream flow gage may be added.

5.2 Mineral Inventory and Energy

5.2.1 Mineral Inventory

A limited number of samples have been analyzed for percent sulfur content. Preliminary results on three species of lizards (Anolis gundlachi, A. evermanni, and A. stratulus) indicate similar values (0.2-0.3%) for all species. Additional individuals will be analyzed and other faunal species processed during the remainder of phase I.

Contents of the bomb calorimeter were subjected to sulfate analysis in order to determine the total sulfur content of the samples burned. Much of the experimental work performed was dedicated to testing methodology which appeared to be just adequate for the sulfur levels encountered in the animal specimens. The results and the estimated uncertainty in results prompts us to review methodology and begin examining other alternatives for S analysis; this is particularly necessary for soil sample examination. Results are estimated to be uncertain by as much as 50% in the worst case and the probably uncertainty in other values is probably at least 20%.

Table 1 presents averages values of the analyses for organic nitrogen (total Kjeldahl nitrogen), nitrate (NO_3-), and nitrite (NO_2-) in 5 samples collected from the surface and bottom of the Rio Espiritu Santo Confluence at Cara del Indio. The organic nitrogen concentration fluctuations appear to be related to those observed for organic carbon, the highest value reported when the highest observed level of the stream occurred.

5.2.2 Calorimetry

Wet weight vs dry weight results for the anolid lizards Anolis gundlachi and Anolis evermanni are depicted in Figure 4. It is clear that individuals whether male or female all retain about the same amount of labile moisture. By dry weight is meant the weight of the animal after 36 hours of drying in a convection oven at 80°C.

The relationship of wet weight to dry weight for Eleutherodactylus coqui is shown in Figure 5. The individuals of E. coqui apparently retain substantially more labile moisture than the individuals of the anolid species. Approximately 81% of the E. coqui was labile moisture whereas the anolid species contained about species 76% moisture by weight.

Heat content of anolid lizard species was determined using bomb calorimetry. The results are tabulated in Appendix A on an "ash-free dry weight" basis. The average heat content for all anolids was:

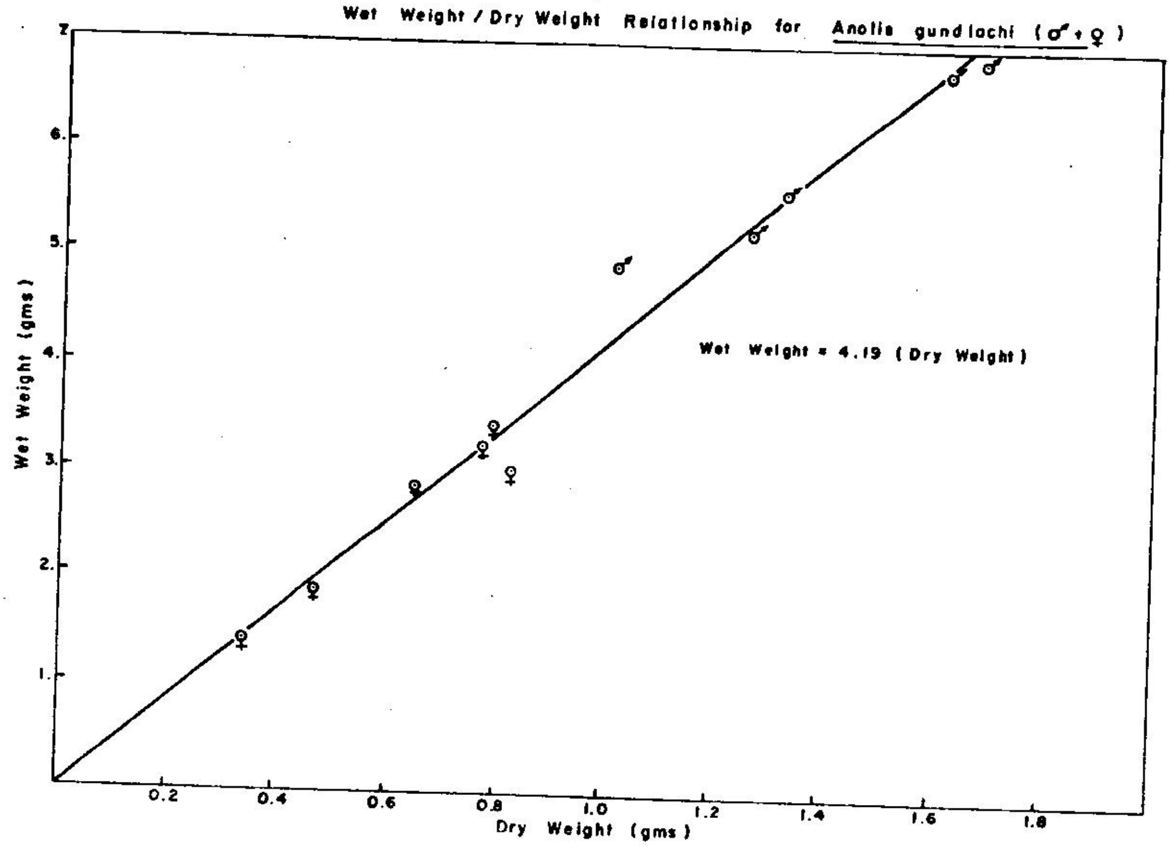
4322.1 cal/ash-free gm. with a standard deviation of:
315.4 cal/ash-free gm.

5.2.3 Carbon Transport

Work has progressed on a new task, the quantification of carbon transport from the forested Rio Espiritu Santo watershed which includes the program study area. Carbon export from the forest is based upon the model for the hydrograph of the Rio Espiritu Santo River presently under development by a visiting scientist, Dr. Oswaldo Rendõn Herrero. That model gages sediment export and weathering using hourly gaging and sediment collection from a flow-monitored stream having a cross-sectional area calibration.

Table 1. Nitrogen, Nitrate, and Nitrite Values from Cara del Indio Sampling Station.

Date (1980)	Total Kjeldahl Nitrogen Concentration (gm/l)		Nitrate/Nitrite Concentration (gm/l)	
	Surface	Bottom	Surface	Bottom
October 9	0.21 ± 0.08	0.13 ± 0.01	0.010 ± 0.007	0.004 ± 0.002
October 30	1.15 ± 0.29	0.90 ± 0.04	0.018 ± 0.006	0.016 ± 0.002
November 17	0.49 ± 0.23	0.65 ± 0.51	0.110 ± 0.067	0.006 ± 0.003
November 25	0.28 ± 0.15	0.57 ± 0.05	0.021 ± 0.033	0.007 ± 0.004



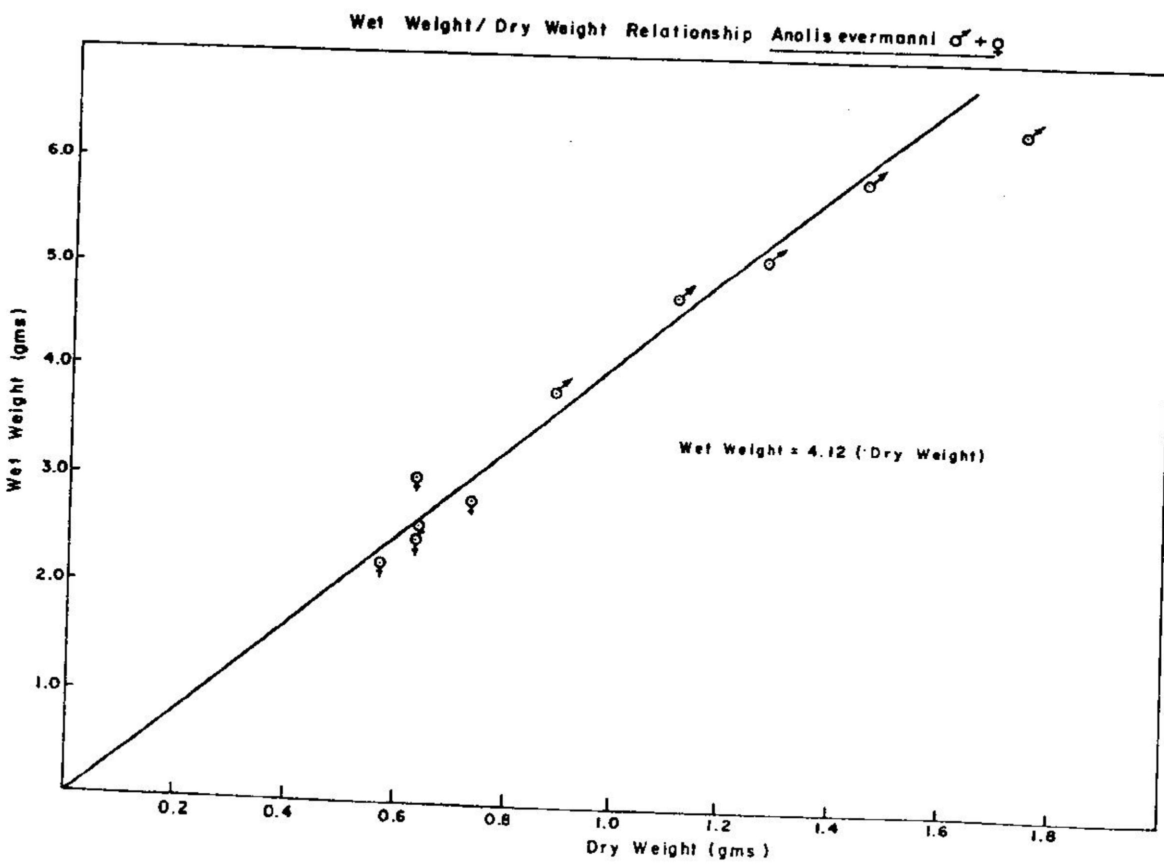


Figure 4. Wet Weight/Dry Weight Relationships for *Anolis gundlachi* and *A. evermanni*.

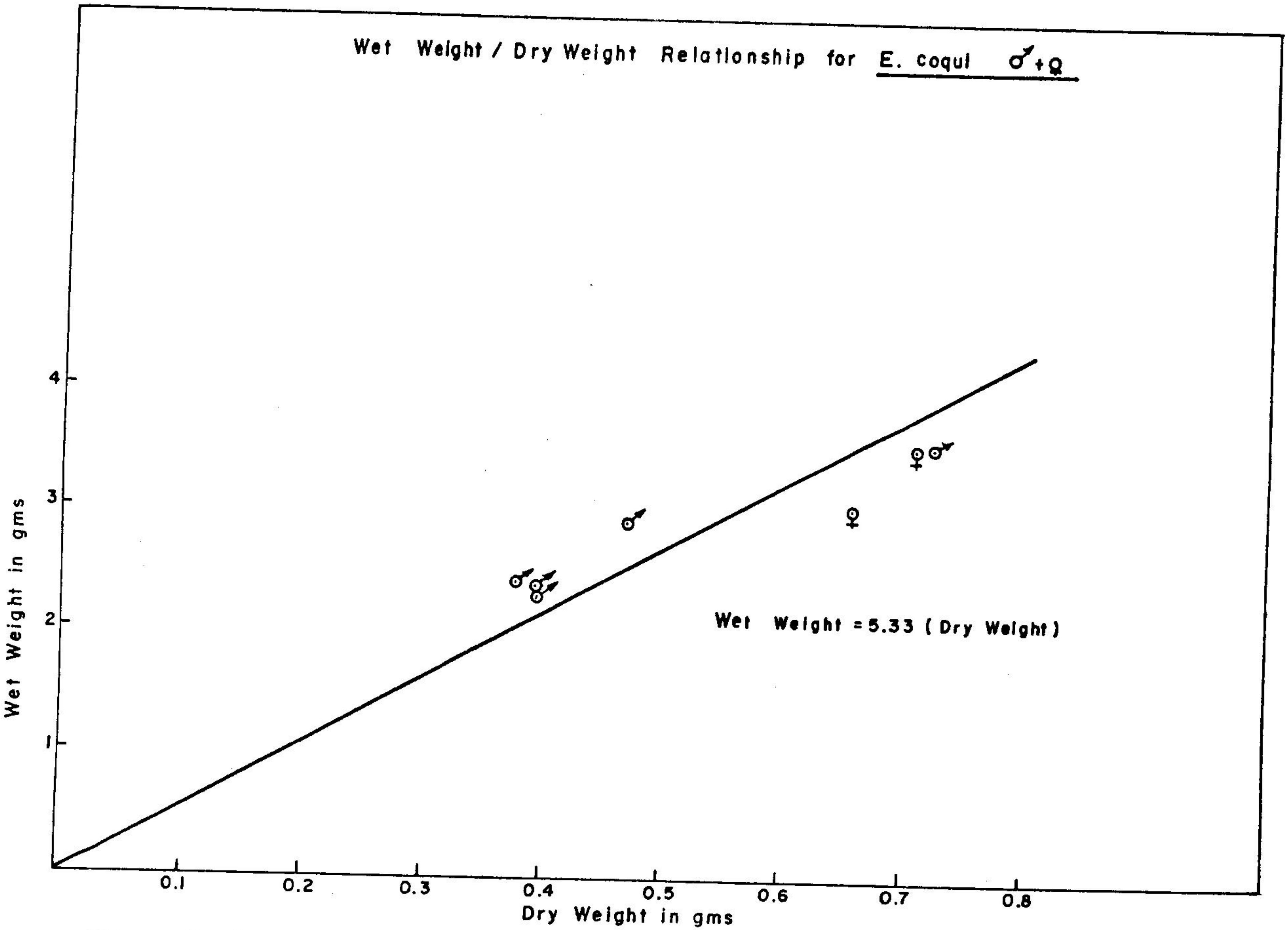


Figure 5. Wet Weight/ Dry Weight Relationship of *Eleutherodactylus coqui*

We hypothesize that long term storage cycles are of limited importance in tropical rain forest. The long term cycle has a requirement for humus and organic soil formation which while important to temperate zone forest carbon fixation is probably of limited significance in the tropical forest. The temperature and humidity in the humid tropics are responsible for rapid decay of leaf material and the 3-4 heavy sediment exporting rainfall events effectively scour parts of the forest ground surface and the sub-surface parts of the forest ground surface and the sub-surface soil layer of its potentially fixable carbon.

Stream Chemistry and Gaging: Water samples were collected from the surface and bottom of the Rio Espiritu Santo River confluence known as Cara del Indio (Indian Face). Samples were processed both before and after either filtration or centrifugation to test the relationship between sediment export and nutrient loss from the forested watershed.

Appendix B lists data for 5 surface and 5 bottom samples collected on each date. The gaging depths are in USGS units and were taken directly from the depth marker at the USGS gaging station at Cara del Indio on Rte. 966. The designations: F and U refer to filtered and unfiltered samples respectively.

Table 2 shows the average values for carbon analysis of 5 samples collected on each of the 4 dates given. The inorganic carbon analysis standard deviations indicate that the collection procedure is adequate to ensure homogenous bulk water samples. Unusually high values of organic carbon observed for bottom samples collected October 9, 1980 and Nov. 25, 1980 may be artifacts of the sampling procedure, and, at least in the case of the November 25, 1980 sampling a larger number of samples could have provided a statistically valid basis for rejection of the high value. On November 17, 1980, the stream level at Cara del Indio was near base flow condition following a period of very heavy showers during most of the previous 12 hour period. The flushing of labile or available carbon from the watershed may account for the low concentration of dissolved organic carbon observed for the 5 samples collected on that date. The only data supporting the hypothesis that heavy export of carbon is large-

Table 2. Carbon Concentrations of Samples from Cara del Indio.

Surface

Date	Organic		Inorganic		Flow Level
	Filtered	Unfiltered	Filtered	Unfiltered	(USGS Units)
Oct. 9/80	3.00±1.19	3.79±1.42	5.55±1.28	6.58±1.21	2.82
Oct. 30/80	5.31±0.49	8.38±0.45	3.63±0.13	3.54±0.06	4.46
Nov. 17/80	0.58±0.13	0.86±0.21	5.68±0.20	5.44±0.98	2.70
Nov. 25/80	4.32±1.88	4.06±2.41	-	-	3.50

Bottom

Date	Organic		Inorganic		Flow Level
	Filtered	Unfiltered	Filtered	Unfiltered	(USGS Units)
Oct. 9/80	5.56±3.79	3.35±3.76	5.72±1.48	5.88±1.24	2.82
Oct. 30/80	5.48±0.17	8.64±0.57	3.60±0.22	3.67±0.16	4.46
Nov. 17/80	0.45±0.09	0.57±0.16	5.72±0.37	5.08±0.87	2.70
Nov. 25/80	3.90±2.84	4.00±3.70	-	-	3.50

ly associated with sediment exportation derives from measurements taken October 30, 1980 when the stream level was the highest of any of the collection times. The differences in carbon concentration in filtered and unfiltered samples is statistically significant.

5.3 Vegetation Studies

Considerable information has been accumulated on the vegetation of the Luquillo Mountains, including the El Verde rain forest (Odum & Pigeon, 1970). Phase I studies are designed to fill gaps in our knowledge of nutrient flows through the ecosystem and to provide a basis for subsequent investigations in phase II.

5.3.1 Plot Characterization and 5.3.2 Phenology

Plot characterization and phenology subtasks are being initiated at this time, but preliminary data is not sufficient for analysis. Litterfall and decomposition studies were given priority because of the length of time needed to obtain results and because of their relevance to overall cycling and transport processes.

5.3.3 Litterfall

Preliminary results give a mean value for October of 1.73 g/m^2 day. Plots 1 through 4 varied from 1.76, 1.29, 1.99 and 1.89 g/m^2. day, respectively.

The leaf fall contributions of the most important species are shown in Table 3. The 1 (highest) through 5 ranking of the species is based on grams of leaves/m^2. day by plot and overall means.

Considerable time was required to establish the litterfall baskets in the forest. As a result, only limited data are presently available and no conclusions are possible. The sampling program has been fully implemented and adequate data will be available for analysis in the phase I final report.

Table 3 . Overall and plot species contribution of leaf fall (ranked from 1-5) based on g dry wt/m^2 · day.

Species	Plot Number 1	2	3	4	Overall
Guarea trichilioides			1		1
Dacryodes excelsa	2	4	2		2
Buchenavia capitata		1		1	3
Manilkara nitida	1		3	4	4
Cecropia peltata				2	5
Casearia arborea				3	
Croton poecilanthus	3				
Sloanea berteriana	4				
Prestoea montana	5				
Inga laurina		2			
Ormosia krugii		3			
Sapium laurocerasus			4		
Philodendron giganteum			5		
Alchornea latifolia				5	
Clusia grisebachiana		5			

Plot 1 through 4 contributed 0.04, 0.04, 0.002 and 0.09 g/m^2.day of flower and 0.07, 0.04, 0.06 and 0.05 g/m^2.day of fruits respectively for the month of October, 1980.

The species contributing the greatest amount (g dry weight) to the October flower component of litter were:

Plot 1. Croton poecilanthus
Plot 2. Homalium racemosum
Plot 3. Homalium racemosum
Plot 4. Byrsonema coriacea

5.3.4 Leaf Decomposition

This task will begin in the 1981 dry season (January-April) and be continued into the following wet season. These methods have been designed to avoid possible errors found in other studies. Weigert (1970) collected litter from the forest floor and oven dried the samples before replacing them in the forest. This method was not used because oven drying the samples before and during the experiment probably killed the decomposers and altered the decomposition rates and because samples collected from the forest floor (loose litter) are in all stages of decomposition.

The following modifications are expected to yield more relevant information:

- placing enough bags in the field so that the collected bags would not need to be replaced after drying
- using freshly fallen leaves to detect rates of decomposition, caloric content changes, and mineral loss

Decomposition rates for individual species will not be measured as were done in the studies of Ewel (1976), Weigert and Murphy (1970). It is believed that leaf composites from each plot will yield the site and species interactions characteristics of each plot and therefore give information of any overall site differences in decomposition

5.4 Faunal Studies

Substantial progress has been achieved in defining major reservoirs and determining principal pathways of nutrients and energy through this rain forest ecosystem. A comprehensive view of the food web organization is emerging which will provide valuable insights into the functioning and complexity of tropical forests. Some of the preliminary results have been unexpected and have caused the redirection of some tasks. It is tempting to integrate our present information, but premature analysis might be counterproductive to program goals and will be deferred until the final report. Individual task results are presented and discussed below.

5.4.1 Invertebrates

Surveys of invertebrates as described in the methods section (4.2) have been delayed because of staffing difficulties. The position has been filled and studies will begin in February, 1981.

Incidental observations and food analysis suggest that complicated and important interactions occur between larger forms (e.g. spiders and whipless whip scorpions) and small species of vertebrates, mainly frogs and lizards.

5.4.2 Amphibians and Reptiles

Habitat searches were performed to determine which species were present in the study area. No new species or unexpected observations were made during seasonal sampling. A compilation of observations made during phase I, and data from literature on the El Verde site will be presented in the report which follows dry season sampling. Species observed in the Study Area during phase I studies are listed in Table 4.

Results of the wet season amphibian abundance surveys are presented in Table 5. *Eleutherodactylus coqui* was consistently the most abundant species, although many of the individuals observed were juveniles and subadults. *E. wightmanae* was the next most abundant species and the only

Table 4 . Amphibian and Reptile Species Observed in the Study Area During Phase I Studies.

AMPHIBIANS

Order: Anura
  Family: Bufonidae
    Species: *Bufo marinus*

  Family: Leptodactylidae
    Species: *Leptodactylus albilabris*
    Eleuterodactylus coqui
    E. portoricensis
    E. richmondi
    E. hedricki
    E. wightmanae
    E. eneidae

REPTILES

Order: Squamata
  Suborder: Lacertilia
    Family: Gekkonidae
      Species: *Sphaerodactylus macrolepis*
      S. klauberi

    Family: Anguidae
      Species: *Diploglossus pleei*

    Family: Amphisbaenidae
      Species: *Amphisbaena caeca*

    Family: Iguanidae
      Species: *Anolis cristatellus*
      A. cuvieri
      A. evermanni
      A. gundlachi
      A. krugi
      A. stratulus

  Suborder: Ophidia
    Family: Colubridae
      Species: *Alsophis portoricensis*

Table 5 . Anurans observed along transects during 1980 wet season surveys.[1]

Species	Average Number Observed Plot No. 1	2	3	4	Relative Abundance Plot No. 1	2	3	4	Average Abundance
Bufo marinus	-	-	0.3	-	-	-	1%	-	<1%
Leptodactylus albilabris	0.3	0.3	-	-	1%	1%	-	-	1%
Eleuterodactylus coqui	43.7	45.3	31.0	28.0	96%	93%	93%	93%	94%
E. wightmanae	0.3	2.0	1.7	0.7	1%	4%	5%	2%	3%
E. portoricensis	0.3	1.0	-	0.7	1%	2%	-	2%	1%
E. hedricki	-[2]	-[2]	0.3	0.7	-	-	1%	2%	<1%
E. richmondi	1.0	0.3	-	-	2%	1%	-	-	<1%

[1]Surveys conducted September 26, 27, 28, 1980 and 25, 26, 29 October, 1980.

[2]Heard calling in plot.

other species observed along transects in all four plots. E. hedricki was heard calling in all plots, but its densities were such that it was encountered on only two transects. Other species are apparently present at very low densities compared to E. coqui. Similar results have been obtained during dry season surveys by Dr. Margaret Stewart during her studies in the same area, and therefore surveys will not be repeated during the 1981 dry season.

Investigation of food habits of Anolis lizards were begun. The minimum number of lizards were collected for the first seasonal survey, but identification of stomach contents is incomplete. The types and frequency of occurrence of food items from the stomachs which have been examined are presented in Table 6. Conclusions from initial sampling are only tentative, but seem to indicate that the same insect orders (Coleoptera, Lipodoptera, Diptera, and Hymenoptera) are important prey items of both species. Anolis evermanni appears to consume more Orthoptera than does A. gundlachi which may be a reflection of different habitat use rather than a true food preference.

Following dry season sampling, all stomach contents will be re-examined and identified more specifically (where possible). Data will be correlated with insect/invertebrate sampling to detect possible food preferences and energy/mineral flow pathways.

Relative abundance and minimum population density estimates for the two most common lizard species (Anolis gundlachi and A. evermanni) are presented in Table 7. Mininum density calculations show higher population levels in plot 4. Inspection of the data show that many of the observations were juvenile lizards on understory vegetation beneath forest canopy which was more open than in the other three plots. Anolis gundlachi was found to be the most abundant species observed in all plots, while A. evermanni demonstrated considerable variability among plots. This may be a result of the small sample size rather than indicating a real difference.

Two additional lizard species were observed along transects Anolis stratulus and A. cuvieri. Both species are primarily found in the forest canopy, and this sampling method consistently underestimates their popul-

Table 6 . Frequency of occurrence of food items in *Anolis gundlachi* and *A. evermanni*.

Food Item	Frequency (%) Anolis gundlachi[1]	A. evermanni[2]
Phylum: Aschelmisthes Class: Nematoda	7	8
Phylum: Mollusca Class: Gastropoda	4	-
Phyllum: Arthropoda Class: Arachnida Order: Araneae	11	16
Class: Chilopoda *Scolopendra* sp.	-	4
Class: Insecta		
Orders: Orthoptera	15	40
Isoptera	7	16
Hemiptera	7	-
Neuroptera	-	12
Coleoptera	59	44
Lepidoptera	30	20
Diptera	56	76
Hymenoptera	70	84
Phylum: Chordata Class: Reptilia Order: Squamata	-	4
Plant Material	7	4

[1] 27 adults (15 males, 12 females)

[2] 25 adults (12 males, 13 females)

Table 7. Average number of individuals, percent relative abundances, and minimum population-density estimates of *Anolis* lizards observed during wet season surveys.

	Average Number of Individuals Observed/Plot		Relative Abundance		Minimum Population Density/ha	
	Anolis gundlachi	*A. evermanni*	*A. gundlachi*	*A. evermanni*	*A. gundlachi*	*A. evermanni*
Plot #1	24.3	3.7	87%	13%	506	80
Plot #2	20.6	3.3	82%	18%	453	113
Plot #3*	24.0	0.7	90%	3%	494	15
Plot #4	29.7	3.7	89%	11%	810	116
Combined Average	24.6	2.8	87%	11%*	566	81

*Four *Anolis stratulus* and 2 *Anolis cuvieri* were observed on transect surveys in plot #3 (average number observed = 1.3 and 0.67; relative abundance = 5% and 2.5% respectively for each species in plot #3).

ation density. Vertical transect studies, not included here, indicate that Anolis stratulus may be an abundant species in the rain forest study area.

The minimum population density estimates are considerably below the absolute estimates calculated by Turner and Gist (1970) for the same area. Relative abundance estimates are also at variance with those presented by Moll (1978) for similar habitat at similar elevations near El Verde. Preliminary data from other lizard studies at El Verde suggest that time of day, weather, and season may all affect the activity and indirectly the observability of species. These questions will receive further consideration during dry season sampling.

It is important to note that these data apply only to the lower 4-5m of the rain forest. Vertical transect studies are being conducted which indicate vertical stratification of lizards, and lizard distribution throughout the 18-22m height of the rain forest. Data from these studies will provide additional data on the relative abundance and distribution of Anolis lizards in the rain forest.

Relative abundance and vertical survey for the first wet season have identified Anolis stratulus, A. gundlachi, and A. evermanni as abundant species within the study area. Because of the vertical stratification of these species, and because population density estimates have not been obtained for A. stratulus (which may turn out to be the most abundant species), studies of population turnover and growth rates have been deferred until data from dry season surveys have been obtained.

5.4.3 Birds

Initial field work on the avian section of the CEER-DOE mineral cycling and transport study has produced both useful results and a new perspective on the problems of sampling and the appropriate techniques to overcome these problems. Moreover, recent developments in avian censusing methods require a re-evaluation of proposed sampling plans, with the result that more accurate population estimates can be generated. Common and scientific bird names are listed in Appendix C.

Population density information was estimated from transect data. Appendix D contains data from transect censuses taken during July-November 1980. The increased number of observations in October and November over preceding months is the result of an increase in avian activity and the addition of a second observer, who was unfamiliar with the Emlen transect methods. An intensive training program since that time has reduced the amount of inter-observer variability to acceptable levels.

The outstanding feature of the data is the dominance of all plots by a single species, the Bananaquit. The Red-necked Pigeon and the Puerto Rican Tody are the next most abundant species in each site, although their relative position changes in different sites. The proportion contributed by each species to the total number of observations remains relatively constant for most species in all sites during July-November. A notable exception is the Red-necked Pigeon, where the number of observations in any month is determined by the occurrence of fruiting trees around which these birds aggregate. In months where a food tree was in fruit near a transect line, observations of this species would be relatively high.

Table 8 gives the total number of observations of each species in each site during the period July-November 1980. The data are corrected for differences in the number of transects and in the total time spent in each plot. Most species show very similar values for all four plots. Six species (Ruddy Quail-Dove, Zenaida Dove, Puerto Rican Emerald, Stolid Flycatcher, Stripe-headed Tanager, Puerto Rican Bullfinch) are twice as common in Plot 4 as in any other plot. Plot 4 is more disturbed than the other three plots, but until vegetation analysis is completed, any explanation for the increased abundance of these six species in Plot 4 is only speculative.

Fifteen of the 21 species observed were found in all plots. Those species found in fewer than four plots were either migrants or very rare residents. With increased observation time, species list for each site are expected to approach complete congruence.

Data from mist-net samples in each plot are shown in Table 9. In almost two weeks of netting, only half the species occurring in the sites

Table 8

Total observations of birds during July-November transect counts corrected for number of counts and time spent in counting.

	Plot 1		Plot 2		Plot 3		Plot 4	
	Birds/ Count	Birds/ hour	Birds/ Count	Bird hour	Birds/ Count	Birds/ hour	Birds/ Count	Birds/ hour
Red-tailed Hawk	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Ruddy Quail Dove	0.4	0.6	0.3	0.4	0.4	0.5	1.0	1.6
Zenaida Dove			0.1	0.1	0.1	0.1	0.2	0.3
Red-necked Pigeon	1.7	2.4	4.5	6.3	2.5	3.5	5.5	8.7
Puerto Rican Lizard Cuckoo	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.3
Puerto Rican Emerald	0.2	0.3	0.4	0.6	0.3	0.4	0.9	1.4
Puerto Rican Tody	2.4	3.3	3.0	4.2	2.6	3.7	2.4	3.9
Puerto Rican Woodpecker	0.8	1.1	2.3	3.1	0.2	0.2	0.8	1.3
Stolid Flycatcher	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.6
Pearly-eyed Thrasher	1.7	2.3	1.7	2.4	0.7	0.9	1.7	2.7
Red-legged Thrush	0.3	0.4	0.4	0.6	0.5	0.6	0.4	0.6
Puerto Rican Vireo							0.1	0.1
Black-whiskered Vireo	0.3	0.4	0.5	0.7	0.7	1.0	0.7	1.1
Black-and-white Warbler			0.1	0.1				
Black-throated Blue Warbler	0.1	0.1						
Louisiana Waterthrush	0.1	0.1			0.1	0.1		
Bananaquit	14.1	20.2	15.5	21.5	12.7	12.9	10.1	16.1
Blue-hooded Euphonia	0.2	0.2			0.1	0.1	0.2	0.3
Stripe-headed Tanager	0.4	0.5	0.6	0.9	0.6	0.8	1.2	1.9
Puerto Rican Tanager	1.2	1.6	1.8	2.6	1.2	1.6	1.8	2.8
Puerto Rican Bullfinch	0.2	0.2	0.6	0.9	0.2	0.2	1.1	1.8

Table 9. Number of captures and capture rate for Plot 1-4.

	Plot 1	Plot 2	Plot 3	Plot 4	Total
Ruddy Quail-Dove	9	16	16	3	44
Puerto Rican Emerald	2	2	2	2	8
Puerto Rican Tody	0	2	7	1	10
Pearly-eyed Thrasher	1	2	2	0	5
Red-legged Thrush	0	0	0	1	1
Black-throated Blue Warbler	0	0	0	2	2
Ovenbird	0	0	1	1	2
Bananaquit	3	2	0	1	6
Stripe headed Tanager	0	1	0	0	1
Puerto Rican Tanager	0	6	0	0	6
Total Captures	15	31	28	11	85
Number of Nets	11	10	10	10	
Number of days	3	3	4	3	
Captures/net-day	0.45	1.03	0.70	0.37	

were captured. This result is consistent with other sites in the wet tropics, where vertical stratification makes some species difficult to catch. The only species caught in numbers was the Ruddy Quail-Dove, a ground feeder. These results suggest that estimation of population densities with marked birds will require the use of canopy nets to capture some species.

Figure 6 presents data on the height of occurrence of seven species. Data were collected during transect surveys and are summed for all four study plots. Figure 6 compares heights of species in two different foraging guilds. Both nectarivores (Puerto Rican Emerald Hummingbird and Bananaquit) and large frugivores (Ruddy Quail-Dove and Red-necked Pigeon) show little overlap in their vertical distribution. The former guild may show more overlap in the canopy, but insufficient data are available at this time to test this hypothesis.

Sixteen birds of six species have been collected and their stomach contents preserved. Weights of these birds and other individuals captured during mist netting for Task 1 are summarized in Table 10. Insufficient observations are available to begin construction of preliminary food webs; however, literature sources have been identified that will contribute much of the information on diet needed for this task.

Nineteen of 60 birds have been captured and are being processed for bomb calorimetry. A detailed protocol for processing bird parts has been developed. Fecal material, food items and stomach contents are being accumulated as the other tasks progress. Difficulty in capturing two species (Red-necked Pigeon and Puerto Rican Woodpecker) may result in these species being omitted from the analysis.

5.4.4 Mammals

No mouse-size mammals were trapped in 80 trap nights in the lines of Sherman line traps, and none have been observed in or near the study area in the recent past. The trapping surveys will be repeated on a larger scale during dry season surveys.

Table 10. . Mean weights (in grams) of seven species caught in mist nets.

	N	$\bar{X}$	S.D.
Ruddy Quail-Dove	38	129.6	16.1
Puerto Rican Emerald	11	3.2	0.3
Puerto Rican Tody	12	6.6	0.5
Pearly-eyed Thrasher	7	96.7	3.4
Red-legged Thrush	4	80.5	2.8
Bananaquit	7	11.1	1.9
Puerto Rican Tanager	4	34.5	0.7

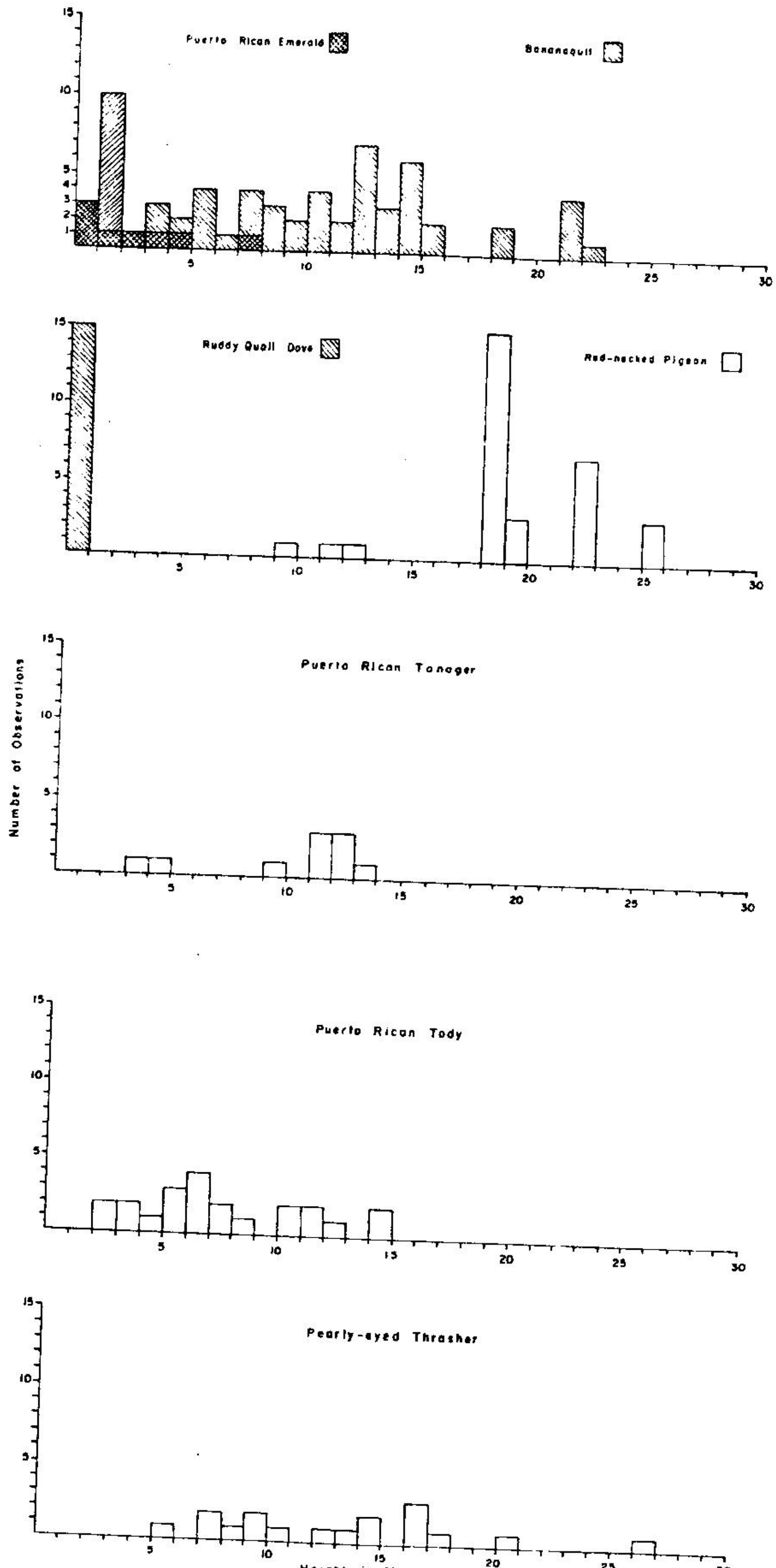


Figure 6. Height of Occurrence of Seven Bird Species in the El Verde Rain Forest

Larger terrestrial mammals had not been surveyd as of November 30, 1980, but the Indian mongoose (Herpestes auropunctatus) and black rat (Rattus rattus) have been observed within the study area. A semipermanent grid, as described in the methods, will be established at plot 3 and surveyed in the near future. This segment of field surveys has been delayed until field team members were immunized against rabies. The Indian mongoose is a major reservoir for this disease in Puerto Rico (Tierkel et.al., 1952).

Horizontal nets placed in the rain forest (plots 1 and 2, at the Sonadora suspension bridge, and near the field station) and a vertical net erected at the field station captured three species of bats: Artibeus jamaicensis, Stenoderma rufum, and Monophylla redmani. All three species have previously been reported from the area(Tamsitt and Valdivieso, 1970). The first two species are frugivorous and the third is nectarivorous. In sectivorous species have not been observed in the rain forest, although some species (e.g. Pteronotus fuliginosa) may forage in openings and above the canopy.

6.0 PHASE I SCHEDULE

Field sampling began in July, 1980 following the selection of sample plots. In spite of the late starting date for some tasks, all phase I field work is scheduled for completion by August, 1981.

A final status report which summarizes and integrates material from all tasks is scheduled for completion by September 30, 1981. Because of the late starting date of some tasks, submission of this report may be delayed slightly. An important part of the report will be an outline of projected phase II research including continued investigations of key organisms and pathways and an outline of planned experimental studies.

Seminars and presentations based an work accomplished in phase I are scheduled to start by May, 1981 following the completion of dry season field work. The workshop which was originally planned has been postponed indefinitely.

It is anticipated that several scientific publications, based on individual tasks studies, will result from this phase.

Manuscripts will be prepared simultaneously with the final report. Papers of a more integrative nature will be written immediately following preparation of the final report and will be given priority over routine project work.

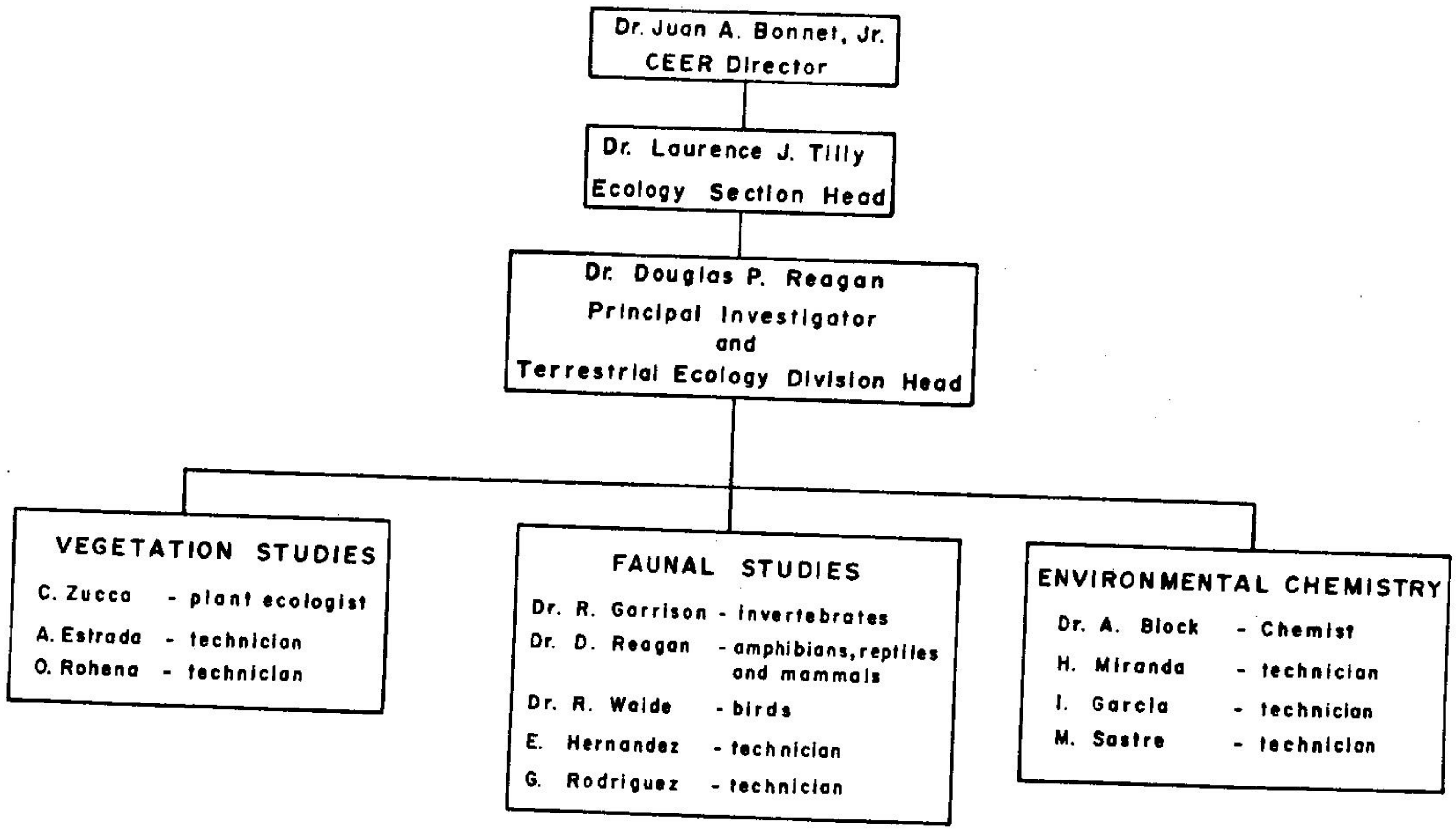
7.0 ORGANIZATION AND MANAGEMENT

The Terrestrial Ecology Division is a unit of the Center for Energy and Environment Research operated by the University of Puerto Rico for the Department of Energy. Field studies are conducted in the Caribbean National Forest from CEER's El Verde Field Station. Chemical analyses and other laboratory investigations are performed at the Terrestrial Ecology Division's facilities in Rio Piedras.

The principal investigator is responsible for program coordination but also has specific task responsibilities. Each major task is supervised by a division scientist. Figure presents the overall program organization.

Collective decisions are made regarding the program execution by all members of the scientific staff including the Terrestrial Ecology Division head, and Ecology Section Head. Ultimate responsibility within CEER rests with the director of CEER Dr. Juan A. Bonnet, Jr. who responds directly to the President of the University of Puerto Rico, Dr. Ismael Almodovar.

Figure 7. CEER Management Structure for the Rain Forest Cycling and Transport Program



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APPENDICES

Appendix A

Calorimetry Data on Anolis Lizards

Species and Sex		Dry Weight	% of Ash	Calories per ash-free gm.
A. gundlachi	♂	1.2674 gms	–	–*
" "	♂	1.6205	31.3%	4580.3 cal/gm.
" "	♂	1.6814	27.6%	4831.3
" "	♂	1.0991	16.2%	4284.2
" "	♂	1.3275	26.8%	4182.0
" "	♀	0.6503	29.4%	–*
" "	♀	0.4622	34.6%	–*
" "	♀	0.7972	15.9%	
" "	♀	0.7701	24.9%	–*
" "	♀	0.8246	13.3%	
" "	♀	0.3337	–**	–*
A. stratulus	♀	0.3743	–**	–*
A. evermanni	♀	1.2751	27.9%	–*
A. evermanni	♀	0.6368	12.5%	–*
" "	♂	1.1175	15.1%	3927.5
" "	♂	0.8864	22.3%	–*
" "	♀	0.6302	23.4%	4895.7
" "	♀	0.5699	13.3%	4093.8
" "	♂	1.7375	26.5%	4181.8
" "	♂	1.4528	22.4%	4119.9
" "	♀	0.7297	22.0%	40.98.8
" "	♀	0.6293	16.9%	–*

* Pair of values rejected according to criteria described in Methods section.

**Insufficient sample for ash measurement.

Appendix B

Carbon Analysis of Stream Samples Collected from Cara del Indio On October 9, 1980, 10:47 AM. Flow Level: 2.82 USGS Units.

Surface Carbon Concentration in mg/l				Bottom Carbon Concentration in mg/l			
Organic		Inorganic		Organic		Inorganic	
F	U	F	U	F	U	F	U
3.43	4.50	6.60	6.40	4.97	3.37	6.1	7.4
2.07	2.56	3.60	4.50	11.73	11.73	6.0	6.0
4.87	5.97	6.76	7.50	5.27	4.47	7.1	6.2
2.00	2.97	5.20	7.20	1.33	2.00	3.2	3.5
2.63	2.97	5.60	7.30	4.50	5.17	6.2	6.3

Carbon Analysis of Stream Samples Collected from Cara del Indio on October 30, 1980, 10:45 AM. Flow Level: 4.46 USGS Units.

Surface Carbon Concentration in mg/l				Bottom Carbon Concentration in mg/l			
Organic		Inorganic		Organic		Inorganic	
F	U	F	U	F	U	F	U
5.24	8.74	3.53	3.62	5.46	8.56	3.57	3.55
6.08	8.64	3.54	3.54	5.25	9.62	3.28	3.46
5.38	8.00	3.58	3.46	5.74	8.50	3.60	3.69
4.77	7.79	3.66	3.58	5.50	8.18	3.65	3.80
5.08	8.75	3.85	3.49	5.46	8.35	3.90	3.85

Appendix B (Cont'd)

Carbon Analysis of Stream Samples Collected from Cara del Indio on November 17, 1980, 11:00 AM. Flow Level: 270 USGS Units.

Surface Carbon Concentration in mg/l				Bottom Carbon Concentration in mg/l			
Organic		Inorganic		Organic		Inorganic	
F	U	F	U	F	U	F	U
0.804	1.142	5.80	5.89	0.573	0.808	5.13	5.13
0.544	0.859	5.70	6.04	0.417	0.670	6.11	3.57
0.457	0.951	5.34	5.47	0.483	0.478	5.80	5.62
0.541	0.717	5.73	6.05	0.460	0.473	5.64	5.72
0.549	0.614	5.82	3.73	0.336	0.433	5.91	5.15

Carbon Analysis of Stream Samples Collected from Cara del Indio on November 25, 1980, 10:45 AM. Flow Level: 3.50 USGS Units

Surface Carbon Concentration in mg/l				Bottom Carbon Concentration in mg/l			
Organic		Inorganic		Organic		Inorganic	
F	U	F	U	F	U	F	U
3.51	3.73	-	-	3.55	2.41	-	-
3.01	3.49	-	-	2.76	2.14	-	-
3.88	2.34	-	-	2.11	2.20	-	-
7.64	8.24	-	-	2.22	2.64	-	-
3.57	2.50	-	-	8.87	10.62	-	-

Appendix C

Scientific names of bird species referred to in the report.

Red-tailed Hawk	*Buteo jamaicensis*
Ruddy Quail-Dove	*Geotrygon montana*
Zenaida Dove	*Zenaida aurita*
Red-necked Pigeon	*Columba squamosa*
Puerto Rican Lizard Cuckoo	*Saurothera vieilloti*
Puerto Rican Emerald	*Chlorostilbon maugaeus*
Puerto Rican Tody	*Todus mexicanus*
Puerto Rican Woodpecker	*Melanerpes portoricensis*
Stolid Flycatcher	*Myiarchus stolidus*
Pearly-eued Thrasher	*Margarops fuscatus*
Red-legged Thrush	*Mimocichla plumbea*
Puerto Rican Vireo	*Vireo latimeri*
Black-whiskered Vireo	*Vireo altiloquus*
Black-anewhite Warbler	*Dendroica caerulescens*
Louisiana Waterthrush	*Seiurus motacilla*
Bananaquit	*Coereba flaveola*
Blue-hooded Euphonia	*Euphonia musica*
Stripe-headed Tanager	*Spindalis zena*
Puerto Rican Tanager	*Nesospingus speculiferus*
Puerto Rican Bullfinch	*Loxigilla portoricensis*

Latin names according to Bond, James. 1979. Birds of the West Indies. Collins, London. 256 pp.

Appendix D

Number of observations of each species/month in Plot 1. Percent contribution to total in parenthesis.

	Jul.	Aug.	Sep.	Oct.	Nov.	No.	Totals
Red-tailed Hawk				1(0.7)		1	0.2
Ruddy Quail Dove		3(5.1)	3(5.1)	1(0.7)	1(0.6)	8	1.7
Red-necked Pigeon	5(10.2)			3(2.3)	26(14.4)	34	7.1
Puerto Rican Lizard Cuckoo			1(1.7)	1(0.7)	1(0.6)	3	0.6
Puerto Rican Emerald			2(3.4)	1(0.7)	1(0.6)	4	0.8
Puerto Rican Tody	3(6.1)	3(5.1)	6(10.2)	16(12.9)	10(10.6)	47	9.9
Puerto Rican Woodpecker	4(8.2)	1(1.7)		1(0.7)	9(5.0)	15	3.6
Stolid Flycatcher				1(0.7)		1	0.2
Pearly-Eyed Thrasher	7(14.3)	7(11.9)	3(5.1)	11(8.5)	5(2.8)	33	6.9
Red-legged Thrush			2(3.4)	1(0.7)	2(1.1)	5	1.1
Black-Whiskered Vireo		5(8.5)				5	1.1
Louisiana Waterthrush			1(1.7)			1	0.2
Black-throated Blue Warble					1(0.6)	1	0.2
Bananaquit	28(57.1)	40(67.8)	39(66.1)	75(58.1)	100(55.6)	282	59.2
Blue-hooded Euphonia			1(1.7)	2(1.6)		3	0.6
Stripe-headed Tanager				1(0.7)	6(3.3)	7	1.5
Puerto Rican Tanager	1(2.0)		1(1.7)	14(10.9)	7(3.9)	23	4.8
Puerto Rican Bullfinch	1(2.0)				2(1.1)	3	0.6
Total observations	49	59	59	129	180	476	
Total time of observations	163	150	136	207	189	845	
Total number of 300 m transects	4	4	4	4	4	20	

Appendix D (Cont'd)

Number of observations of each species/month in Plot 2. Percent contribution to totals in parenthesis.

	Jul.	Aug.	Sep.	Oct.	Nov.	No.	Totals
Red-tailed Hawk			1(1.1)		1(0.6)	2	0.3
Rudy Quail Dove			1(1.1)	3(1.2)	1(0.6)	5	0.8
Zenaida Dove				1(1.4)		1	0.2
Red-necked Pigeon	9(25.7)	5(6.9)	15(16.9)	19(7.8)	38(21.7)	86	14.0
Puerto Rican Lizard Cuckoo		2(2.8)				2	0.3
Puerto Rican Emerald			2(2.2)	4(1.6)	2(1.1)	8	1.3
Puerto Rican Tody		5(6.9)	9(1.1)	32(12.3)	11(6.3)	57	9.3
Puerto Rican Woodpecker		8(11.1)	7(7.9)	14(5.8)	14(8.0)	43	7.0
Stolid Flycatcher				1(0.4)		1	0.2
Pearly-eyed Thrasher	3(8.6)	4(5.6)	6(6.7)	14(5.8)	6(3.4)	33	5.4
Red-legged Thrush	1(2.9)	2(2.8)	1(1.1)	1(0.4)	3(1.7)	8	1.3
Black-whiskered Vireo	1(2.9)	8(11.1)	1(1.1)			10	1.6
Louisiana Waterthrush			1(1.1)	3(1.2)		4	0.7
Black-throated Blue War.							
Black and White Warbler					1(0.6)	1	0.2
Bananaquit	17(48.6)	36(50.0)	44(49.4)	135(55.6)	62(35.4)	294	47.9
Blue-hooded Euphonia							
Stripe-headed Tanager				4(1.6)	8(4.6)	12	2.0
Puerto Rican Tanager	4(11.4)	1(1.4)	1(1.1)	8(3.3)	21(12.0)	35	5.7
Puerto Rican Bullfinch				5(2.1)	7(4.0)	12	2.0
Total observations	35	72	89	243	175	614	
Total time of observation	171	145	167	160	177	820	
Total number of 300 m transects	3	4	4	4	4	19	

Appendix D (Cont'd)

Number of observations of each species/month in Plot 3. Percent contribution to totals in parenthesis.

	Jul.	Aug.	Sep.	Oct.	Nov.	No.	Totals
Red-tailed Hawk			1(1.7)			1	0.2
Ruddy Quail Dove			2(3.3)	2(1.2)	3(2.2)	7	(1.6)
Zenaida Dove	1(2.0)					1	0.2
Red necked Pigeon		5(12.2)	9(15.0)	10(6.1)	25(18.6)	44	(10.9)
Puerto Rican Lizard Cuckoo					2(1.5)	2	0.4
Puerto Rican Emerald		1(2.4)	2(3.3)	1(0.6)	2(1.5)	6	1.3
Puerto Rican Tody	3(5.9)	3(7.3)	6(10.0)	23(13.8)	17(5.2)	52	11.5
Puerto Rican Woodpecker				3(1.8)		3	0.7
Stolid Flycatcher				1(0.6)		1	0.2
Pearly-eyed Thrasher	1(2.0)	2(4.9)	4(6.7)	6(3.6)		13	2.9
Red-legged Thrush				6(3.6)	3(2.2)	9	2.0
Black-throated Blue Warbler							
Black and White Warbler							
Bananaquit	36(70.6)	21(51.2)	33(55.0)	97(58.8)	66(49.3)	253	56.1
Blue-hooded Euphonia			1(1.7)			1	0.2
Stripe-headed Tanager			2(3.3)	2(1.2)	8(6.0)	12	2.7
Puerto Rican Tanager	2(3.9)	2(4.9)		13(7.9)	6(4.5)	23	5.1
Puerto Rican Bullfinch	1(2.0)				2(1.5)	3	0.7
Black Whis ered Vireo	7(13.7)	7(17.1)				14	3.1
Louisiana Waterthrush				1(0.6)		1	0.2
Total observations	51	41	60	165	134	451	
Total time of observations	154	147	199	183	166	849	
Total number of 300 m transects	4	4	4	4	4	20	

Appendix D (Cont'd)

Number of observations of each species/month in Plot 4. Percent contribution to totals in parenthesis.

	Jul.	Aug.	Sept.	Oct.	Nov.	No.	Totals
Red-tailed Hawk		1(1.2)			1(0.5)	2	0.4
uddy Quail Dove	2(3.8)	3(3.6)	2(4.7)	4(2.6)	7(3.8)	18	3.5
Zenaida Dove		3(3.6)				3	0.6
Red necked Pigeon	9(17.3)	11(13.1)	6(14.0)	12(7.8)	61(33.2)	99	19.2
Puerto Ric			2(4.7)	1(0.7)	1(0.5)	4	0.8
Puerto Rican Emerald		4(4.8)		5(3.3)	7(3.8)	16	3.1
Puerto Rican Tody	2(3.8)	10(11.9)	2(4.7)	20(13.1)	10(5.4)	44	8.5
Puerto Rican Woodpecker		8(9.5)	2(4.7)	4(2.6)	1(0.5)	15	2.9
Stolid Flycatcher		2(2.4)		3(2.0)	2(1.1)	7	1.4
Pearly-eyed Thrasher	5(9.6)	3(3.6)	5(11.6)	7(4.6)	10(5.4)	30	5.8
Red-legged Thrush	1(1.9)	2(2.4)	1(2.3)	3(2.0)		7	1.4
Puerto Rican Vireo				1(0.7)		1	0.2
Black Whiskered Vireo		12(14.3)				12	2.3
Louisiana Waterthrush							
Black-throated Blue							
Black and White Warbler							
Bananaquit	28(53.8)	24(28.6)	15(34.8)	66(43.1)	49(26.6)	182	35.4
Blue-hooded Euphonia				3(2.0)		3	0.6
Stripe-headed Tanager	2(3.8)			10(6.5)	9(4.9)	21	4.1
Puerto Rican Tanager		1(1.2)	6(14.0)	11(7.2)	14(7.6)	32	6.7
Puerto Rican Bullfinch	3(5.8)		2(4.7)	3(2.0)	12(6.5)	20	3.9
Total observations	52	84	43	153	184	516	
Total time of observations	101	163	83	181	151	679	
Total number of 300 m transects	4	4	2	4	4	18	