leyan University is to measure the curve of this decline over a certain distance at both ends of equatorial and polar diameters. An on-line computer analyzes the curves to find the edge, and a laser interferometer measures the diameter within a fraction of a wavelength of the laser light. The experiment, at Kitt Peak National Observatory, should be able to determine if there is any difference in the two diameters. If there is it should be only a few milliseconds of arc. First Hill must calibrate his equipment so that he can subtract out about 100 milliseconds of instrumental error. To do this he needs observations of the sun at all times of day. The telescope is used for other things so Hill can use it only a short time each day. The rains set in in Tucson six weeks early (at the end of May), so he has not been able to complete the calibration.

A related problem, as Dicke puts it, is that brightness differences between points on the edge of the sun may masquerade as oblateness. His technique is to use a revolving slit that exposes a portion of the whole edge of the sun and integrate the flux in the hope of removing anomalies due to brightness differences.

The radio and radar ranging of the planets can also be used to determine the amount of relativistic time delay produced by the sun's gravity as the signal passes close to the sun. To obtain such data, passage times are compared for signals taken when the planet is far from the sun and when it is nearly behind the sun. This has been done several times with Mercury and Venus, and has generally supported Einstein. In this case, though, the difference between Einstein and Brans-Dicke is only a few percent, and greater accuracies are sought in the measurement. Another way to do the same experiment, with possibly greater accuracy, was to observe the quasar 3C 279 as the sun passed in front of it. The gravitational slowing of the radio waves produces a bending of the beam; as the sun passed in front of it, 3C 279 should have appeared to move out of its true position. The result, says Richard Sramek of the National Radio Astronomy Observatory, is 94 percent of what Einstein predicted. But the uncertainty is 6 percent, and the result is not conclusive.

Cosmologists hope for a conclusive result. Modern cosmology is based on Einstein's theory. Lately quite a number of anomalies have shown up: galactic redshifts that appear to defy theory, the mystery of where the quasars are, sources of electromagnetic and gravitational radiation that appear fantastically large. If Einstein is not correct, some of these things may be explicable by proper alterations in gravity theory. If he is correct, other explanations will have to be found. □

'This is the forest primeval'

Biome researchers want a model of the total deciduous forest

by Joan Arehart-Treichel

Although land east of the Mississippi contains two-thirds of all Americans, it still boasts rich and productive forests. Which of these forests should be retained? Which should be turned into farmland, cities, suburbs, highways or industrial complexes? When pesticides are sprayed on a deciduous forest, what happens to photosynthesis of forest leaves? What effects does forestry have on animals in a forest? How does dumping of heavy minerals affect plants in forest lakes or watersheds? These and related questions are pressing for answers based on scientific facts.

In the past few years ecologists have attempted to examine isolated aspects of the eastern deciduous forest, or of the lakes, streams, birds, insects, mammals, weather and other ecosystems that comprise the larger environment, or "biome." However no scientist or group of scientists dared to take an intensive look at the total forest. During the past year and a half, however, some 200 ecologists from different specialties and universities throughout the eastern United States have risen to the challenge. They are working under the auspices of the Eastern Deciduous Forest Biome of the International Biological Program.

The work they are doing is important, not only to science but to humanity, and a great deal of peer judgment went into the program before the National Science Foundation and Congress supported it. "I think we have several interrelated goals," Stanley Auerbach of the Oak Ridge National Laboratory in Tennessee and director of the program, says. "One goal is to develop a group of interdisciplinary environmental researchers who can work effectively on environmental problems covering a broad area of the United States and considering them in regional context. A second goal of the program has been to develop a base of knowledge that will enable us to deal more effectively with environmental problems that are crowding in on us in the eastern United States. These problems are increasingly calling for a synthesis of ecological knowledge in a fashion that society, and particularly people concerned with development and technology, can understand. A third goal of our studies is the development of data banks and information that can be drawn upon to answer pressing environmental questions."

When asked how the goals of the studies are being met—they are to terminate officially in July 1974 when the IBP ends—Auerbach replies, "We have been more successful in building teams in one and a half years than I would have expected, taking 200 investigators from different backgrounds and sitting in different universities and getting them interested, enthusiastic, and most importantly, willing to share their ideas and data. As far as obtaining knowledge, I think we have made a useful start. The questions we are trying to answer are complex and will probably take a good 10 years to answer fully. Regarding the data bank, we have just made the beginnings of a start. It is

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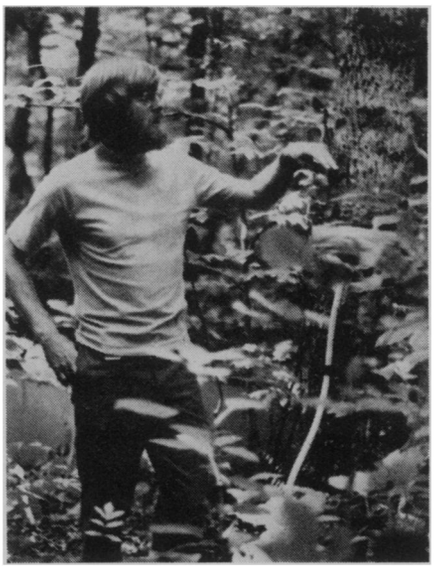
Frank Harris checks out rainfall accumulation at one of the forest sites.

tough and is going to call for hardware, people and techniques to put vast amounts of collected data into giant computers."

The five study sites of the Eastern Deciduous Forest Biome include Lake Wingra in Wisconsin, administered by the University of Wisconsin; Lake George in New York, administered by Rensselaer Polytechnic Institute in cooperation with the State University of New York at Albany and other colleges; Triangle Research Park in North Carolina, administered by Duke University; Coweeta, also in North Carolina, administered by the University of Georgia; Oak Ridge in Tennessee, administered by the Oak Ridge National Laboratory. A large number of other colleges, universities, state and Federal agencies are also contributing to the studies. A visit to the Oak Ridge site where all the site activities are being coordinated gives one a good feel for progress being made at all the sites.

The Oak Ridge forests, located near the mist-enshrouded Smoky Mountains, are 15,000 lush hectares in extent. On the whole they have been little disturbed since they were purchased by the Atomic Energy Commission and the Oak Ridge National Laboratory some 30 years ago. In recent months the Oak Ridge biome researchers have been collecting literally thousands of items of information about some of these forests. Some of their data is a confirmation of facts previously obtained by investigators in the laboratory, or by naturalists or the U.S. Forest Service. For example: The species of trees at Oak Ridge are more numerous than those found around Lake George or Lake Wingra. Tree limbs and trunks give off carbon dioxide as well as take it in, although the amount they give off is far less than they take. Tree trunks shrink at night because they pump less water up to branches and leaves than during the daytime.

The Oak Ridge ecologists have also obtained some unexpected findings. For instance, they were surprised at the amount of oxygen the densely populated eastern deciduous forest gives off. That amount might have implications for atmospheric oxygen supplies in the eastern United States. Frank Harris, one of the scientists working in watershed research, says, "I was struck by the tremendous contributions that annual root turnover contributes to mineral cycles." David Reichle, Oak Ridge site coordinator, was curious how much of all carbon dioxide available in the forest is given off by plant-eating animals. Carbon dioxide output is a good indication of the energy role of animals and plants in the forest. Reichle found that 65 percent of carbon dioxide comes from plants, 34 percent from bacteria and fungi in the soil and less than one



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Edwards collects tree trunk juices.

percent from plant-eating animals.

"As a result," Reichle concludes, "we know that the decomposers—bacteria and fungi—are far more important to the total energy system of the forest than we thought. In brief, if we don't understand what forest decomposers are doing, we really can't understand carbon dioxide output and energy balance in the forest."

Biome ecologist Robert Van Hook has been taking inventory of who eats whom and how much. He is now trying to determine what kinds and quantities of elements pass through the forest food chain. He says he is surprised to find there is much less sodium than calcium or potassium in plants. What's more, plant-eating animals contain about four times as much sodium as do plants, suggesting that herbivores must eat a lot of plants to meet their sodium needs.

Nelson Edwards, another site investigator, believes the approaches the Oak Ridge team is taking are every bit as important as their results. "I think we are doing what few other ecologists have done—measuring variables in the forest rather than in the laboratory, and many variables at the same time." For example, carbon dioxide exchange of oaks, hickories and tulip trees, three major tree species in the Oak Ridge forests, are being monitored hour by hour, day by day, week by week, as are contingent forest variables—soil water potential, leaf water potential, sunlight levels, leaf pigment concentrations, nutrient levels, and others.

It is this continual, simultaneous monitoring of many forest components, in fact, that allows the investigators to proceed to their next objective, systems analysis modeling, which is expression of interactions of forest components by mathematical analogies. They may find, for example, that if a particular temperature and moisture exist on the forest floor, then microorganisms on the forest floor will give off a specified amount of carbon dioxide. They draw up an equation to express the relationship that exists among the three components. They return to the forest floor and alter one of the variables. If the equation holds, they conclude that it accurately expresses the real forest interactions. If the equation is not completely accurate, they correct it and return to the forest to test the correction —again by altering one of the interacting components while holding the others constant. Generally the more an equation is refined, the better model it becomes. "At each point of modeling and remodeling, you do your damndest to get it right," Hank Shugart, site modeler, asserts.

At present the Oak Ridge researchers have some completed models—for water movement through a watershed, for example. Given rain levels, the model can predict soil, moisture and runoff. Other models have been drawn up and are now being tested. Still other completed models, like that for leaf photosynthesis, are being expanded to take in other forest variables.

By July 1974, when the IBP and biome studies officially terminate, the models the forest biome team has come up with will provide an arsenal of information and predictive answers for scientists, civil engineers, foresters, urban planners, industrial developers, farmers and other decision-makers. Models from the five sites will be compared, some general conclusions drawn about all of them. Biome studies west of the Mississippi (SN: 10/23/71, p. 282) will also end by then, if not sooner. According to John Neuhold, program director of ecosystems analysis at the National Science Foundation, "Efforts will be made to see some generalities across the models from all the biomes for broadly continental kinds of applications."

Additionally, models obtained at the eastern deciduous forest sites, like those obtained from western biome studies, will provide a basis upon which ecologists can further explore and model ecosystems and biomes. As Reichle puts it, "We are studying ecosystems like physiologists study cells, putting variables together into a system. This is the new science, the new ecology we're shaping."

"When the official IBP ends," Auerbach declares, "we will have demonstrated the efficacy of using an integrated, structured approach, taking individualistic scientists and putting them into a goal-oriented program. We are creating a new kind of ecologist. This may be our most important contribution." ❑