

23 EXPEDITION RESEARCH PROJECTS IN TROPICAL FORESTS

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The ecology of tropical forests and their biota presents an enormous range of opportunities for field research. Any biological project carried out in tropical forests is going to bring the expedition members close to a wide range of plants and, to a lesser extent, animals, many of which are likely to be completely new to science. There will rarely be a simple, straightforward textbook that will aid identification, even of the common species. A local scientist who knows his or her flora is indispensable to the success of any expedition that wants to work on the ecology of tropical forests.

The complex environments of tropical forests provide great opportunities for short duration studies of local variations in microclimate and soil characteristics, and of hydrological and geomorphic processes. In thinking about the types of project that may be feasible in any particular forest area, the variety of forest types and terrain present must be considered.

In most localities contrasts exist among ridge crest, slope, valley floor and floodplain sites. In many localities, patches of disturbed forest are close to natural forest, providing opportunities for comparative studies of the impacts of people on the forest.

Inevitably, many forest study sites are remote and conditions for setting up instruments for field monitoring are difficult. The high humidity often makes electronic instruments inoperable and battery life short. Experience suggests that only instruments that have proven reliability under rain forest conditions are worth using by expeditions, and that rechargeable batteries, replaced every few days, are the only way of guaranteeing continued operation of battery-powered recording instruments.

Even though tropical rain forests are wet environments, long periods without rain can occur, e.g. at the Danum Valley Field Studies Centre in Borneo, annual rainfall averages some 2800 mm, or more than 230 mm per month. However, in April 1991, the rainfall was only 24.2 mm, nearly all the days that month being dry. Projects relying on measuring rainfall and water flows may be frustrated and expedition planners should have alternative projects in case the weather is unusually dry.

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Any expedition intending to work in a tropical rain forest should obtain and study Tim Whitmore's book *An Introduction to Tropical Rain Forests* (1989) and, for those going to Asia or the Pacific, *Tropical Rain Forests of the Far East* (1984).

CLIMATIC, MICROCLIMATIC AND METEOROLOGICAL OBSERVATIONS

The difference in microclimate between the interior of the forest and the open provides many opportunities for comparative investigations. Temperature and humidity show diurnal (daily) fluctuations, with open areas warming up far more than the forest interior during the daytime, whereas humidity within the forest is much more constant. Simple thermometers and hand-held whirling hygrometers read at half-hourly or hourly intervals could provide basic information. Clockwork, chart-recording, wet and dry bulb thermometers, or more sophisticated data loggers would be preferable.

The vertical zonation of temperature and humidity in the forest is of great interest. One simple way of obtaining a vertical temperature profile is to use a catapult to send a line across a high bough of a tree, and then to haul up a rope on to which are fixed maximum and minimum thermometers at intervals of, say, 5 or 10 m. The rope can be hauled down as frequently as required for the instruments to be read.

Within the forest the spatial variability of throughfall (the rain penetrating through the vegetation canopy) is even greater and the value of observations of both throughflow and stemflow (the rain running down tree trunks) is high. To be useful, such measurement schemes have to be carefully designed. The average of the catch of all the gauges, randomly relocated, can be compared with the catch in the open, to give an indication of the percentage of the rainfall intercepted, i.e. not arriving at the throughfall collectors.

A small part of the rain falling on the forest runs down the tree trunks as stemflow. This is measured by fitting collars around trees to divert the stemflow into collectors. Such collectors are easily made from epoxy resin, which can be moulded into the required shape before it hardens.

Meteorological observations of the types described above could be used to establish differences in the conditions in primary forest, secondary forest, grassland and open areas or, in an undisturbed forest, among natural gaps, closed forest, slopes and river banks.

Soil temperatures are poorly known, and soil thermometers could be used to assess thermal conditions at sites along a soil catena. Temperature and humidity observations are safe topics, whereas with rainfall there is always a risk that the expedition may coincide with an unusually dry period.

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STUDIES OF SOILS AND FOREST FLOOR CONDITIONS

The forest floor is a key part of the forest ecosystem. The plant debris that falls to the floor is attacked by decomposing organisms, releasing nutrients that are added to soil, taken up by plants or lost to drainage waters.

Litterfall rates can be assessed by establishing simple traps under various types of forest canopy. Essentially a litter trap is a fine gauze mesh suspended between four posts about 50 cm above the forest floor. Usually about 1 m² in area, the traps should be emptied every day, or at frequent intervals, otherwise insects will have already destroyed part of the material. The litter may be dried, in the sun if an oven is not available, and weighed, to obtain an estimate of the litterfall per m². A simple classification into leaf, twig, other plant fragments, insects and other debris may be attempted. As litterfall varies seasonally and depends on wind and rainfall, time is a constraint on the value of results from short-term studies. Comparisons of litterfall in different types of forest, and particularly between natural forest and secondary regrowth, would be most useful.

A wide range of assessments of the physical properties of soil may be made in the field, including measurements of infiltration, bulk density and permeability. Infiltration can be measured using a double-ring infiltrometer; this is made of two rings, possibly of strong plastic of the type used for gas mains, or of metal, 20 cm deep and one ring about 30 cm diameter and the other 36 cm. The two rings are driven into the ground. A known quantity of water is applied to the ground surface inside the inner ring, and the time taken for that water to infiltrate is calculated. The result is converted into the depth of water infiltrating in one hour. Infiltration rates vary greatly with soil types, from 10 to 27 cm/h over a range of soils in Puerto Rico.

Bulk density measurements require access to a balance, but are easily accomplished if one is available. Permeability may be measured using a field permeameter, which is easily constructed in a workshop but would have to be thoroughly tested before being taken on an expedition. Details of these techniques are readily available in texts such as those edited by Goudie (1989) and Landon (1984). If a field test requires a ready water supply or needs basic laboratory facilities, its accessibility must be ascertained in advance.

Soil description in the field, by excavating soil pits and examining soil profiles (a major activity on many expeditions), is particularly valuable on a downslope catena if linked to studies of litter and slope hydrology. The percentage silt-clay content of a soil, a good indicator of water-holding capacity, can be obtained by sieving if a 63 mm mesh sieve, lid and collecting pan are taken in the field, and water and a good balance are available.

Investigations of soil erosion and nutrient loss

Concern about the impacts of forest disturbance has led to many proposals to measure erosion and the removal of chemical elements in solution. In planning to

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undertake such studies, the episodic nature of erosion must be recognised. A few heavy rainstorms may carry away nearly all the soil eroded in a year. An expedition may be lucky to sample such a major event, but probably it will not do so. Comparative studies are therefore more appropriate for short-term projects. The second factor is the level of logistic support for such investigations. Chemical analyses are possible only if portable field analytical kits are available, if local laboratories are able to assist, or if an adequate number of samples can be taken back to the home country base for analysis. Concentrations of most dissolved substances in tropical rain and river waters are extremely dilute, usually less than 10 mg/l for most elements. If field analysis is planned, the field kit must be able to give reproducible results for such low concentrations. As samples deteriorate with storage without refrigeration, transport back to home base for additional analyses may be unwise. Analytical specialists or geochemists should be consulted before finalising the programme.

Notwithstanding the necessary cautionary approach to erosion studies, highly valuable projects can be carried out, particularly when disturbed areas subject to large amounts of erosion are compared with one another. A typical project might be to investigate erosion on abandoned logging tracks, one of which has uninterrupted flow of surface water downslope, the other having barriers to trap sediment and impede water flow. Water can be tested for temperature, pH and conductivity using small field meters, but many such instruments are unreliable under humid tropical conditions. The pH cells must be kept in standard solutions except when in use. Conductivity reflects the chemical composition of water and thus is useful, for reconnaissance studies, to test whether tributary streams have similar solute contents or to identify where major changes in water quality occur. Levels of dissolved oxygen indicate the potential of streams for aquatic life, but dissolved oxygen meters must be calibrated with standard solutions. Before buying or borrowing such field instruments, advice should be sought on their suitability and robustness under tropical conditions.

Stream water quality is an excellent environmental indicator. In the Amazon basin, rivers are described as black water, white water and clear water rivers. The acidic, dilute, black waters are found in many sandy podzolic areas of the tropics, including large areas of coastal peats and freshwater swamp forests. Classifying rain forest aquatic environments in this way, by water testing over a wide area, is an ideal expedition project. A field check using pH and conductivity meters is advisable before selecting sites for water sampling in a study designed to highlight environmental contrasts

If a major storm occurs during an expedition period, the opportunity should be seized to resurvey any stream for which debris data had already been collected.

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INVESTIGATIONS OF RIVER MORPHOLOGY AND FLUVIAL PROCESSES

Rivers draining rain forests differ enormously according to the geological history of their catchment areas and the climatic regime of their part of the tropics. Detailed observations of the form and process of river channels in the tropics are needed to improve flood prediction and forecasts of sediment load. Simple surveys of channel cross-sections and mapping of channel bed materials and vegetation provide useful information. Mapping of the distribution of sediments of different sizes in the channel and on gravel bars helps to establish the material available for transport during high flows. Measurements of sizes and the lithology of pebbles, preferably using the 4- to 6-cm long axis class, help to establish the way that rock fragments change shape and lithologies are eliminated with downstream transport. Tropical vegetation grows rapidly, but on river channel margins it shows a zonation related to flood frequency. Mapping this riverine vegetation, with simple descriptions in terms of life-forms, gives a good indicator of annual and extreme flood heights.

Small streams are often encumbered with large amounts of broken tree trunks and branches, some of which form debris dams that trap sediment being transported downstream. Such debris dams are washed out during the biggest storm events or exist until they rot away. Although they have been well studied in the wet temperate forests of the west coast of North America, they have seldom been investigated in the tropics. Simple surveys of the amounts of coarse woody debris and numbers of debris dams in streams of different sizes, and the lithology, gradient and disturbance by people would add to the understanding of how biological and hydraulic factors work together in rain forest streams. Many have hypothesised that tropical streams exhibit minor fluctuations during calm weather as a result of the daily evapotranspiration cycle. If a simple river level gauge, in the form of a graduated board or staff, can be erected on a stream bank, hourly observations, day and night, could enable any such fluctuation to be tested. This work could be coupled to air, soil and water temperature measurements, pH and dissolved oxygen determinations to reveal whether there are significant diurnal variations. Ideally such observations could be repeated on streams of differing characteristics. Many of these projects involving aspects of the hydrological cycle and fluvial processes could be combined together in a team study, with individuals having responsibility for different components, such as rainfall and interception, slope processes, channel form and river water quality. Detailed studies of soil properties and hillslope hydrology have been integrated in this way.

THE IMPACT OF VARYING DEGREES OF FOREST DISTURBANCE

Although much remains to be learnt about the undisturbed natural rain forest, even

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more information is required about what happens in areas that have been logged, cleared, replanted or abandoned to secondary regrowth. Usually patches of such modified forest are readily accessible and provide good opportunities for short-term comparative investigations. In particular, areas of soil compaction, such as logging roads, places where logs were assembled, abandoned construction sites and tracks along which logs were dragged, may be investigated to determine the density of the vegetation at a certain time after cessation of the disturbance, the proportion of water still running over the surface, the amount of organic matter on the soil surface, the size and length of any rills and gullies, and any other evidence of the rate of recovery from disturbance. All the projects relevant to natural forest are relevant to disturbed or secondary forest.

PROJECTS STUDYING BIODIVERSITY

The tropical forest is one of the richest habitats for plant and animal diversity (see Prance, 1982) and some simple but informative work can be undertaken comparing animal and/or plant diversity across different habitats, altitudes, vegetation formations, regions or countries. This kind of project lends itself to longer-term recording and can be the aim of successive expeditions from the same institute/university. Nadkarni and Longino (1990) compared invertebrates in the canopy and in the forest floor litter in montane forests in Costa Rica. Samples of the litter were sifted for the following groups and the numerical dominance was counted: mites, adult beetles, holometabolous insect larvae, ants, collembola, amphipods and isopods. All were easy to identify by the non-specialist. Similar work was carried out by Collins (1979a) and his team in Gunung Mulu National Park. The foraging activity of insects such as termites can be intensively studied for short periods and can result in data worthy of publication (e.g. Collins, 1979b).

Getting into the canopy of forest trees has long been both a physical challenge and scientifically rewarding. Several accounts and techniques have been documented, which are best summarised by Mitchell (1986), but see also Whitacre (1981). Assessment of arthropod diversity in the canopy has been a subject of much debate over the past 10 years (Stork, 1988), but comparative quantitative studies of tropical insects, especially in relation to plant host specificities, are projects worthy of consideration. The technique using knock-down insecticide fogging, which can be set up in the forest canopy by a competent expedition, can collect large numbers of insects on sheets laid out on the forest floor.

STUDIES ON FOREST ECOLOGY

Biomass variation in different forest formations usually needs longer periods than are available on short-term expeditions but restricted comparisons of interest can be

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made. Forest inventories measuring all trees with a DBH (diameter at breast height) of 10 cm or more in a 1-hectare linear transect (10 × 1000 m) to show diversity, frequency, density and dominance can be a worthy objective (Boom, 1986). It must be linked with collecting good herbarium specimens of each species (which can be from 90 to more than 200 species per hectare) for later determination. This is a project that would benefit by having a local forester or botanist join the team, or at least have someone in the local forest herbarium identify the species. This also provides a good opportunity to collect information on local names and uses of the plants. Invariably only a number of the trees will be flowering, and very difficult even to see, let alone collect. Good herbarium material will always be welcomed by the local national herbarium, which should always be offered the first set of any collected material. Herbaria here in the UK (Natural History Museum, Royal Botanic Gardens, Kew and Edinburgh) will always be pleased to have duplicates of any named material, but may not be in a position to identify these plants for you.

Studies in leaf morphology in relation to forest type and altitude zonation, especially if a field microscope can be taken in, can show how plants adapt themselves to different environmental extremes. Other projects could compare structure and even physiology (e.g. photorespiration rates) of plants in sun and shade (see also Medina et al., 1977). These physiological investigations can use simple apparatus, which should be tried out before leaving the UK.

PROJECTS INVOLVING STUDIES OF EPIPHYTES

The tropical forest abounds in epiphytes, e.g. orchids, many ferns, the screw-pine family (Pandanaeae), the pineapple family (Bromeliaceae), aroids of all forms (climbers such as *Philodendron* to single but often enormous plants of the genus *Anthurium*) and many others, but the diversity is not that great and, given good herbarium material collected in the field, the species can usually be identified. Lichens and bryophytes are other epiphytes that are more abundant in the canopy and on the more stunted trees of the upper montane forest (elfin forest). There are also specialised lichens and bryophytes, mainly liverworts, which grow specifically on leaves of young trees and larger herbs in the lower montane and lowland TRF. These folicolous species can be difficult to identify but are easy to collect and with specialist help can be tackled on one's return. Specific studies on the distribution of mosses and lichens in relation to host specificity and position on the trunks of those host species could add substantial knowledge to an underworked field.

Such projects must be backed up by well-prepared specimens to identify the components of these relationships, so familiarity with collection and preservation techniques is needed.

Vascular plant epiphytes often have complex structures to catch or retain leaf litter, e.g. special leaves as in some ferns such as the stagshorn (*Platyserium*) and

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basket ferns (*Drynaria*). Both the roots of the fern and other epiphytes get nutrients from these aerial peat pockets. Ants and termites play a significant role in establishing these aerial gardens (Huxley, 1980), carrying up sand grains and other detritus. In a large mature crown a very wide spectrum of plants from woody rhododendrons to small sedges can live undisturbed for many years. Roots also have complex structures, which help in water absorption/retention, and interesting anatomical studies can also be instigated.

PROJECTS THAT STUDY THE INTERRELATIONSHIPS OF PLANTS AND ANIMALS

The interdependence of plants and animals presents interesting problems, e.g. flower pollination and seed dispersal. Studies on nectar production and its relation to microclimate in bird-pollinated species, e.g. *Heliconia* spp., can elucidate the role that the plant itself plays in the feeding rate of pollinators. The study of ant plants (see Huxley, 1978, 1980) and the role of ants in preventing herbivory opens a wide field for observation when you are camping in the forest.

ECOLOGICAL PROJECTS ON VERTEBRATES

Any programme involving larger vertebrate populations usually requires more time in the field than is available to the average expedition. Exceptions to this rule will be found when naturalists or zoologists of considerable experience are attached to the expedition (compare Medway and Wells, 1971; Medway, 1972). Studies on range, feeding habits and breeding behaviour of birds are frequent objectives for expeditions and ornithological teams should contact specialists at Birdlife International. Baiting, capture and recapture of various animals (fish, amphibians and other trap-pable vertebrates) can give useful information on population size or location distribution patterns.

Work on plotting and describing amphibian breeding sites, collecting tadpoles and adults, together with sound recordings of their mating calls, opens up a number of avenues for projects, especially where a range of altitude can be covered.

PROJECTS ON THE ECOLOGY AND BEHAVIOUR OF INVERTEBRATES

Many projects on smaller animals, especially invertebrates, e.g. insects, can be carried out. Studies of invertebrates should be linked with the existing programme of a professional entomologist in order to maximise the data obtained, because there will be many species new to science in a project of this nature.

Studies on activity patterns or reproduction rates, e.g. in relation to temperature

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and other microclimate states, can be carried out in the few months available (e.g. Larsson, 1990), as can studies on the feeding habits of invertebrates (e.g. Monk and Samuels, 1990). Territory ranges of certain flying insects can also be studied. Investigations into the faunal composition of forest water bodies, e.g. tree holes, water caught or secreted in leaf bases, specialised organs such as flower bracts in gingers and related plants, and insectivorous pitchers of the genus *Nepenthes*, stimulate one to think of the use of such water bodies to the plants themselves, and the interrelationships of the animals that live there. Life cycles are often extremely short where the water bodies are ephemeral and animals can often be bred through to the adult stage in the few weeks available on an expedition. Interesting short-term studies were made on *Heliconia*, a banana-like plant of the American tropics that has hard horny persistent floral bracts. These hold liquid, most of which is secreted by the plant (Vandermeer et al., 1972; Bronstein, 1986). Identification to species is not necessary to give the spectrum of life forms found and their adaptation to the microhabitats that these sites provide.

THE IMPORTANCE OF PREPARATION

Work in tropical forests is hot and uncomfortable, despite the splendid ecological variety and complexity of the environment. Everything possible must be done before departure to ensure that projects will work and instruments will function. All equipment and techniques should be thoroughly tested in a forest environment near the home base before departure. Check carefully the assistance available in the field and find out what restrictions or regulations there may be on taking samples out of the field area or the country, or on importing them to the home country.

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FURTHER INFORMATION**Useful addresses and websites**

Centre for International Forestry Research (CIFOR). Website: www.cifor.cgiar.org/
 Edinburgh Centre for Tropical Forests, Pentlands Science Park, Bush Lane, Penicuik, Edinburgh EH26
 oPH. Tel: +44 131 440 0400, fax: +44 131 440 0440, website: www.nmw.ac.uk/ectf
 European Tropical Forest Research Network, c/o Tropenbos International, PO Box 232, 6720 AE,
 Wageningen, website: www.etfrn.org
 Global Canopy Programme, John Krebs Field Station, University of Oxford, Wytham, Oxford OX2 8QJ.
 Tel: + 44 1865 724 222, website: www.globalcanopy.org
 Global Forest Watch at www.globalforestwatch.org
 New York Botanical Garden, Bronx, NY 10458-5126, USA. Tel: +1 718 817 8700, website: www.nybg.org
 Organization for Tropical Studies:
 North American Office: Box 90630, Durham, North Carolina 27708-0630 USA. Street address: OTS,
 Duke University, 410 Swift Ave. Tel: +1 919 684 5774, fax: +1 919 684 5661, email: nao@duke.edu
 Costa Rican Office: Apartado 676-2050 San Pedro, Costa Rica. Street address: 400 mts Oeste del
 Colegio Lincoln, diagonal a plaza Los Colegios, Moravia. Tel: +506 240 6696, fax: +506 240 6783, email:
cro@ots.ac.cr
 La Selva Biological Station: Apartado 676-2050, San Pedro, Costa Rica. Tel: +506 766 6565, fax: +506
 766 6535, email: laselva@sloth.ots.ac.cr
 Las Cruces Biological Station: Apartado 73-8257, San Vito, Coto Brus, Costa Rica. Tel: +506 773 4004,
 fax: +506 773 3665, email: lasrucres@hortus.ots.ac.cr
 Palo Verde Biological Station: Apdo. 49-5750, Bagaces, San Pedro, Costa Rica. Tel: +506 661 4717,
 fax: +506 661 4712, email: paloverde@ots.ac.cr, website: www.ots.ac.cr
 Programme for Belize, 1 Eyre Street, PO Box 749, Belize City, Belize. Tel: +501 275 616, website:
www.pfbelize.org
 Pro-Natura International, Pro-Natura USA, 8123 Heatherton Lane, 104, Vienna, VA 22180 USA.
 Tel: +1 703 641 5900, website: www.pronatura.org.br
 Rainforest Information Centre, PO Box 368, Lismore, NSW 2480 Australia. Website:
www.rainforestinfo.org.au
 Rainforest Concern, 27 Lansdowne Crescent, London W11 2NS. Tel: +44 20 7229 2093, fax: +44 207 221
 4094, website: www.rainforestconcern.org
 Works with the Ecuadorean Maquipucuna Foundation.
 Rio Mazan Project, The Greenhouse, 48 Bethnel Street, Norwich, Norfolk NR2 1NR. Tel: +44 1603 611953,
 fax: +44 1603 666879
 A small independent charity working for the conservation of Andean forests.
 Royal Botanic Gardens Edinburgh, Inverleith Row, Edinburgh EH3 5LR. Tel: +44 131 552 7171, fax: +44 131
 552 0382, website: www.rbge.org.uk
 Royal Botanic Gardens, Kew, Richmond, Surrey TW9 3AB. Tel: +44 20 8332 5000, fax: +44 20 8332 5197,
 website: www.rbgekew.org.uk
 Smithsonian Institution, 1000 Jefferson Drive, PO Box 37012, SI Building Room 153, MRC 010,
 Washington DC, 20013-72 USA. Website: www.si.edu
 Tambopata Reserve Society (TreeS - UK), c/o John Forrest, 64 Belsize Park, London NW3 4EH. Tel: +44
 20 7722 8095, website: www.geocities.com/treesweb/index
 Tropenbos Foundation, Lawickse Allee 11, PO Box 232, 6700 AE Wageningen, The Netherlands. Website:
www.tropenbos.nl
 Tropical Biology Association, Department of Zoology, University of Cambridge, Downing Street,
 Cambridge CB2 3EJ. Tel: +44 1223 336619, fax: +44 1223 336619, website: www.zoo.cam.ac.uk/tba

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Tropical Conservation and Development Program, Center for Latin American Studies, University of Florida, 319 Grinter Hall, PO Box 115530, Gainesville, FL 32611-5530, USA. Website: www.latam.ufl.edu
 UK Tropical Forest Forum, Jane Thornback, c/o Natural Resources Institute, Central Avenue, Chatham, Kent ME4 4TB. Tel: +44 20 8332 5717, fax: +44 20 8332 5278, website: www.forestforum.org.uk
 World Rainforest Movement, Unit 1c, Fosseyway Business Centre, Stratford Road, Moreton in Marsh, Glos GL56 9NQ. Tel: +44 1608 652893, fax: +44 1608 652878, website: www.wrm.org.uk
 World Resources Institute, G Street, NE (Suite 800), Washington DC 20002, USA. Tel: +1 202 729 7600, fax: +1 202 729 7610, website: www.wri.org

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