



British Bryological Society

Special Volume No.3

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A GUIDE TO COLLECTING BRYOPHYTES IN THE TROPICS

B.J. O'SHEA



Syrrhopodon rupestris

BRITISH BRYOLOGICAL SOCIETY
CARDIFF
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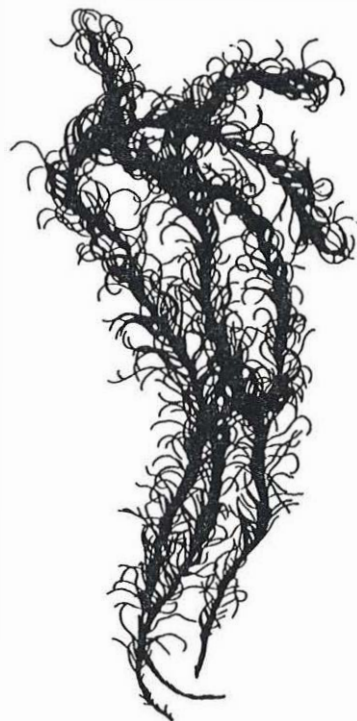


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A Guide to Collecting Bryophytes in the Tropics

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A Guide to Collecting Bryophytes in the Tropics

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1. Introduction

This guide is intended for any individual or group going to collect bryophytes in the tropics. Experience has shown that general purpose expeditions are often not successful in making useful collections of bryophytes: often only the commonest and most conspicuous specimens are collected. *Octoblepharum albidum* was called 'missionary moss' by the eminent bryologist H.N. Dixon because of the frequency with which it was collected by the inexperienced, and all the 'bryophytes' of one university expedition proved to be lichens. Even experienced bryologists from temperate regions do not always make good collections unless they are prepared to expend effort in familiarising themselves with the tropical flora before they go. This guide is produced with the intention of providing the necessary guidance to maximise the scientific value of tropical collecting expeditions.

There is a strong feeling against collecting amongst conservation-minded botanists, perhaps because historically there has been a 'stamp collecting' mentality amongst botanists. They often saw their herbaria as collections of 'one of everything', rather than as reference collections which could be used to assist in future identification, in distributional studies, or for taxonomic studies. Some plants, including bryophytes, have been collected out of existence in the UK, and it is said that there is more material of some very rare plants in herbaria than there is in the wild. The UK flora is very well known, and is thus particularly susceptible to such threats.

In the tropics, the position is rather different. Very few areas are well enough known to be able to predict where rare or endangered bryophytes are to be found and thus deliberate over-collecting is unlikely to be a problem. Over collecting is also not a problem in areas that are endangered by external threats to the environment, such as dams or logging, and indeed for some collecting, for instance for chemical analyses, quite significant quantities may be needed. In most areas of the tropics, so little collecting has been done that almost any collecting is likely to be useful. The exception is the main tourist areas at locations such as Luquillo Mountains (Puerto Rico), Kilimanjaro (Kenya) and Kinabulu (Sabah) which have been quite well documented so

that there will be little benefit in the non-expert making collections. (Permits are also required for collecting in such places.)

But why is collecting bryophytes from the tropics important? There are two main reasons. The first is the pursuit of scientific knowledge, which should need no explanation or justification to anyone going on a scientific expedition. The majority of the world's bryophytes exist in the tropics, yet they remain the least known. There is often a problem in identifying plants from the tropics because of the poor state of tropical bryophyte taxonomy (and the lack of relevant literature - see later). Consequently attempts to understand tropical ecology are limited because of the problems of being certain about what plant is being studied. In many tropical environments, bryophytes form a significant part of the flora, but the study of their ecology is restricted to the few who can actually identify them. As most tropical ecologists are not bryologists, this diminishes the relevance of their work. The more information we can get about bryophytes, the more it will be possible to help those attempting a synthesis of knowledge about the tropics.

The second reason is one of survival. About a third of all tropical forest has been felled or degraded already, and the rate is being maintained at about 20 to 40 hectares per minute. Most of this disappearing forest is botanically unknown, and thus potentially important information about specific plants, and also more general information of relevance to other areas, has gone without trace. Bryophytes are important in two major ways. Firstly, they have specific properties that make them important as the source of various chemical products of great potential value to mankind. This has been known for some time about flowering plants, but increasingly it is becoming clear that bryophytes also possess a number of biologically-active substances, such as anti-carcinogenic compounds, anti-microbial substances etc. and that the greatest variety of these occur in tropical climates (see Ando and Matsuo (1984) for a summary of these and other uses). The better understanding we have of the floristics of these plants, the easier it will be to exploit knowledge of bryophyte biochemistry. Secondly, bryophytes appear to play a vital rôle in nutrient cycling and buffering in forests, as well as in water relations. Evidence about this is only just emerging, and this knowledge can only be gained by field investigation and the information derived from collecting.

This guide does not cover the planning or equipping of an expedition in any detail, only how to go about preparing for your trip and what to do when you get there to make sure your collecting trip is worthwhile for both you and science. The tropics may be an exotic place for you, but it is part of everyday life to the people who live there, so your attitude to them is important. Show your care and concern for both the local people and their environment to make your trip truly worthwhile.

If you have any comments on the material in the guide, please let the author know, and also get in touch if you have any queries - we have no intention of providing an expedition planning service, but we may be able to point you to the information you need.

2. Preparation

2.1 *The tropics* In deciding to make a trip to the tropics, you should already have a good idea about what you can expect to find when you get there, but you should make sure you have seen such publications as Richards (1975), Jacobs (1981), Longman and Jenik (1987) or Whitmore (1984) for tropical forests, Walter (1971) for the non-forested tropics, and Myers (1984) or Caulfield (1985) for the tropics in general, and Pócs (1982) and Richards (1984) for bryophyte habitats. For more specific information about a particular country or area see Davis et al (1986), and Greene and Harrington (1989) for available bryological literature.

2.2 *Planning* There are several excellent books and booklets about planning an expedition (which also contain pointers to more specialised books), so this is not covered here in any detail. Examples are Gifford (1983), Blashford-Snell and Ballantyne (1977), and the publications of the Royal Geographical Society's Expedition Advisory Centre (EAC), such as Chapman (1988). Anyone planning a trip should contact the EAC at 1 Kensington Gore, London SW7 2AR (01-581 2057). Two short papers (Mori and Holm-Nielson, 1981; Delgadillo, 1987) on botanical/bryological trips to the tropics, although aimed primarily at professional botanists, are nevertheless of great value to any collecting trip in looking at both opportunities and constraints. Books on backpacking and 'travelling on a shoe-string' will also be useful if you are not well-financed (e.g. Lonely Planet Guides, Moon Guides, Frommer 'Dollarwise' guides). Hatt (1985) is a cheap and useful general book about travelling in the tropics.

Research the trip thoroughly, and know what to expect in the tropics in general, and in your target country (geography, language, customs, currency, weather etc.). Make sure all participants are taking it seriously and are similarly prepared, work out costs in detail and allow a generous contingency, find out what clothing is appropriate, consider medical requirements, get injections organised well in advance, organise your visas and discover what limitations there are likely to be on tourists. Work out the logistics of travel (how to get about with your team and equipment) making any bookings before you go if you can - it may take days arranging a trip across country when you are there. If you need to hire porters or guides, make sure you

know how to go about doing this and how much the going rate is. This is likely to be much more successful if it is arranged locally for you, so a contact in the area is very useful. This will also help you over local laws, especially about collecting and travelling in remote or conservation areas. It should also alert you to any particular dangers including insects, snakes and other animal life, guerrilla activity etc. - be aware of the dangers and know how to deal with them, but don't panic.

Accommodation should be arranged before you go. Using tents or 'dormobile' type vehicles gives flexibility, but makes it less easy to get specimens dried. Missionaries are usually very welcoming, and it may be possible to use a mission as a base, or just for a night or two.

If the weather is seasonal and you can choose a time of year, go shortly after the rainy season, when the bryophytes will be at their best.

You may find throughout your trip that dealings with officialdom are eased if you travel as a tourist rather than as a scientific expedition.

The Embassy or Tourist Bureau of your destination country should also be able to provide information, as might specialist travel agencies - but all this should be found in more general guides such as those mentioned at the start of this section.

If you can, talk to your local experts about which bryophyte groups or geographical areas need particular attention - this may provide a focus for your expedition. Try the local bryological society (the BBS in the UK - address on the front page of this guide) (O'Shea, 1985), or the local herbarium (see below). The wet tropics, rich in both quantity and variety of bryophytes, may appear the most attractive area to visit, but drier areas are much less well-worked, and the plants are different and of interest because less well-known.

2.3 Overseas contacts, invitations and collecting permits The most valuable source of assistance in making your trip worthwhile is likely to be a contact in the area you are visiting - but you must be able to demonstrate the seriousness of your intent before somebody who doesn't know you will make any effort to help. This means amongst other things having someone concentrating almost solely on bryophytes, and that person being able to demonstrate some expertise. If you do not already have a contact, you could try looking in the International Association of Bryologists' Compendium (Vitt, Gradstein and Iwatsuki, 1985), which lists bryologists and herbaria in most countries in the tropics, or write to the Botany Department at the University nearest

to your destination. You will find that an offer to collect for a tropical herbarium can be used to solicit a written invitation from that country, which is almost essential for fund raising. You may not even be allowed to collect if there is no local collaboration. A local contact will also advise where collecting permits are essential (National Parks, Nature Reserves, etc.).

Many South American countries nowadays require you to have a permit (to be obtained via a local herbarium) for collecting anywhere in the country. Moreover, part of each collection needs to be deposited in a local herbarium. Some local herbaria may require you to deposit labelled specimens before you leave the country. It is obviously essential to be aware of such rules before embarking on a collecting trip in these countries. See Delgadillo (1987) for more details.

2.4 Funding The Directory of Grant-Making Trusts (published by the Charities Aid Foundation) and Grants Register (Macmillan) are very useful, but take a lot of going through and result in a huge amount of letter writing - most of which is likely to be fruitless. The EAC have a small booklet listing the most useful sources of funds, and private companies are also worth trying.

2.5 Maps It is useful to have good large-scale maps, and Stanford's (12-14 Long Acre, London WC2E 9LP) is the best source. They also stock a wide range of travel guides. Map libraries are also useful, such as that at the Royal Geographical Society (RGS). Look also at geological maps. This will give some idea of which areas might be promising to visit.

2.6 Expedition reports Writing up your expedition is essential. It is a good idea to look at a range of expedition reports to see what others have done, as not only will they give you an idea of what is required, but they may give you guidance on how other expeditions have prepared themselves. Botanical Gardens such as Kew or Edinburgh will have these, as does the library of the RGS/EAC.

2.7 Herbaria/libraries It is important to visit a bryophyte herbarium before a tropical trip, to survey relevant literature and to look at specimens from the region to be visited. These are usually part of the "lower plants" or "cryptogamic" herbarium at the British Museum (Natural History) in London, Edinburgh Botanical Garden, the National Museum of Wales at Cardiff, or possibly at a local museum or herbarium. Telephone beforehand to make sure that it is convenient to visit, and that there is someone there to show you where things are (and for local museums, to check that they have appropriate tropical collections/literature). Their experienced staff will be able to provide advice and information on many parts of the world. It can also be very useful to visit herbaria while you are in the tropics,

and indeed may sometimes be obligatory (see 2.3 above).

2.8 *Types of expeditions* Two-person trips are probably best, organised specifically to meet bryological needs. However, it is sometimes useful to join a larger, interdisciplinary expedition (e.g. a Royal Society expedition) where you may be relieved of some or all of the organisation. This may involve some compromising on areas to be visited, which may not include the best ones for bryology.

3. How much do you need to know about bryophytes ?

This document does not tell you how to distinguish bryophytes from other plants: if you are unfamiliar with bryophytes, you are probably not yet ready for a tropical collecting trip. Collecting bryophytes in the tropics will be much more profitable if you are already familiar with your local plants, particularly with the range of variation that can be expected, so that you know what distinguishes one bryophyte taxon from another. If your trip is still some time away, and you have time to get to know bryophytes before you go, first of all look at the standard texts: Watson (1981) and Smith (1978) in the UK, and also Schofield (1985) for a more general account. If this doesn't put you off (it takes some time to become familiar with even the common ones amongst the thousand or so taxa in the UK - so think of the problems of coping with a flora that could be even larger) attend some meetings of your local bryological society (O'Shea, 1985) or find a local bryologist who will help you. You should certainly be able to distinguish between the main bryophyte groups, such as acrocarpous and pleurocarpous mosses, the Metzgeriales, Jungermanniales and Marchantiales in the hepatics, and the hornworts, as well as having examined some of the commoner tropical bryophytes. Usually the large and conspicuous plants are well-known; the dull and the inconspicuous may ultimately be more profitable. Even a little knowledge will make a big difference to your effectiveness, but I must emphasise that your collection will be significantly more useful if you are already familiar with bryophytes, and no expedition should set with the main object of studying bryophytes unless its members already have some reasonable knowledge of bryophytes.

4. Where to look

Most mosses and liverworts prefer moist, shaded places, although there are a few species restricted to deserts and other dry habitats. Normally, however, the moister the situation, the greater is the development of the bryophyte population, and in tropical areas they may compose the greatest part of the visible vegetation. Wherever clouds and moist winds strike mountainsides through the greater part of the year, the forest may be so overgrown and draped with mosses that the

trees can hardly be seen, and a tree trunk may actually be only half its apparent diameter. In other forests (particularly lowland forest), the degree of shade may be sufficient to severely inhibit bryophyte growth, with most of the flora being in the forest canopy. If you are visiting a drier area (see also para. 2.1) choose the wet season to visit. Generally, providing there is enough light, the warmth and wetness provide good conditions for bryophytes throughout the tropics. The ecology of tropical bryophytes is covered well in Pócs (1982) and Richards (1984).

It is worth considering four main tropical substrates in more detail: water, trees, soil and rock.

4.1 *Water* In general, lowland tropical streams and rivers are not rich in bryophytes, although they are a somewhat neglected habitat, and there are interesting (and probably new) taxa to be found, as well as a few plants that are confined to these habitats. A rather more interesting flora is found in mountain streams. In running water bryophytes will always be attached to rocks, tree roots or the stream bed, but some will almost always be submerged, whilst others will only occasionally be submerged. In standing water, a few liverworts may be found floating free, and there is often an interesting ephemeral flora around fluctuating ponds, growing on bare mud. Although some bryophytes can tolerate brackish conditions or occasional salt spray, the coast is not usually a productive area, although a few bryophytes usually can be found on old mangrove trees.

4.2 *Trees* Probably no trip to the tropics will omit the forest habitat, but cultivated land is also productive because of the greater light, and also because the trees are more accessible.

On trees in dense forests, the height above the base of the tree at which particular species of bryophytes grow depends on light and humidity. Light intensity increases from the ground upwards, but relative humidity decreases (and wind movement also increases), so that inside a forest, bryophytes such as *Frullania* and *Macromitrium* spp. which require good light and are tolerant of low humidities, are found mainly in the tree canopy. On isolated trees in clearings, parks, savannas, orchards etc., the canopy species grow much lower down, often nearly to ground level. A rich bryophyte flora can often be found near the ground for instance on old cocoa trees in plantations, but these are often fairly common species. Different kinds of tree have different bryophyte floras, although the species of tree is probably less important than such things as bark acidity and chemistry, and on the quality of the bark as a substrate: smooth and flaky bark will usually have a poorer flora than rough bark. When collecting bryophytes from trees, a sharp knife is essential, and a scrap of bark in the packet may add to its scientific value, (although

there are simply too many tree taxa to be able to identify them from pieces of bark). Fallen branches and twigs should always be examined, as should fallen trees - it may be the only way of seeing what grows at the top of the tree, unless you have tree climbing apparatus (see below). Trees are perhaps the most complex of bryophyte habitats in the tropics, because the base, different levels of the trunk, the crotches, the branches and the twigs may all have different species.

In addition, in a moist forest, many bryophytes are epiphyllous (growing on leaves), and the leaves of small trees and shrubs will be covered with bryophytes - mostly small liverworts - as will buttresses, if there is enough light. You will usually have to collect whole leaves in this case, as it is easier to collect a leaf rather than trying to scrape the epiphylls from the leaf surface. It is also best to collect whole twigs where these are covered with pendulous bryophytes, despite the problems they bring in fitting them into a herbarium. See the paragraphs on collecting for further details.

In dense forest, much of the forest life exists in the canopy. There are now several books describing the "enchanted canopy" (e.g. Mitchell, 1986; Perry, 1986), and Perry in particular spends some time describing in outline the mechanics of getting into the canopy and moving about in it, but this requires a set of skills and equipment that you may not have with you. However, several bryologists have managed to climb trees successfully and safely (e.g. ter Steege and Cornelissen, 1988), usually by using a bow to shoot a light cord over a high branch, and then hauling up a climbing rope. The rope is then climbed using "ascenders", which is hard work and takes a long time, but is safe and straightforward provided you have someone with you who has climbing experience and is familiar with ropes, slings, karabiners and ascenders. Where conservation is not important (see para. 1) it may be easier to have trees felled to get to the canopy bryophytes. In general, however, fallen branches and recently felled trees will be sufficient.

It is not safe to climb trees if you are alone, whether to collect bryophytes or to see where you are.

Lowland forests have always been assumed to have a rather small bryophyte flora, in contrast to the variety of phanerogams, but recent evidence suggests that lowland forests, particularly canopies are much richer than previously thought. Montane forests (especially 'cloud' or 'elfin' forests) are, though, much richer in both variety and quantity.

4.3 *Soil* Bryophytes growing on soil are particularly important in

seasonally wet habitats in climates with dry seasons, such as savanna etc., especially on banks of streams. They show the same intolerance of variation in environment as bryophytes on trees, and the resulting narrow selection of habitat is characteristic of these plants. Some species will be more or less restricted to heavy, water-holding clays, whereas others are always on sand or gravel. Whether the soil is acidic or basic is extremely important to bryophytes, and as this may be characteristic for a species, it is necessary to be able to recognise this either by testing or through knowledge of the rest of the flora. Prior research on the geology of the area will help. The amount of moisture available at one season or throughout the year, the amount of shade or sunlight, and whether the ground is flat or inclined are all factors which determine directly the species of mosses and liverworts which occupy any habitat. An excellent illustration of this intolerance is that we can expect, and find, totally different moss populations in open clay fields and on deeply shaded clay banks in a ravine. The clay is the same, but the other environmental factors are radically different.

In open clay fields, dried up ponds or on mud flats along rivers, very small mosses, thalloid liverworts and hornworts may be found which are often overlooked, and could thus be very interesting. Old termite mounds are a good habitat for some bryophytes, such as *Fissidens* and *Dicranella* species. Man-made habitats are worth examining.

Within lowland forests, bryophytes rarely grow on the ground. Where there is exposed ground it is often acid, even on basic rocks. The type of soil which most markedly affects the bryophyte flora is the white sand found in Amazonia, the Guianas, Borneo etc., which has a different flora from the usual clayey red or yellow lateritic soils. Another factor is altitude: there are more bryophytes on banks of trails and roadside cuttings at higher elevations.

4.4 Rock A single large rock may form the home for a dozen different bryophytes. Just as on trees, those at the base will be moisture loving, and those on top will be less so, depending on the exposure of the rock. The relative amount of light will have a large effect, so different sides of an isolated rock will have different amounts of bryophytes as well as different species. As with soils, the composition of the rock is extremely important, and alkaline rocks such as limestone will support an entirely different population from acidic rocks such as granite or quartzite. Be prepared to look for very small species, particularly of liverworts; you will need a knife to scrape these from the rocks. The ceilings and walls of caves into which daylight enters should also be examined.

Look as well at man-made habitats, not only where natural rock is used, but also on brick (particularly on the mortar) and concrete.

Culverts may combine dampness and decaying concrete, so may have interesting species growing in them.

Without doubt, the most significant factor affecting bryophyte growth is the amount of moisture available. Mosses growing on tree trunks well above the ground or on exposed rocks will depend almost entirely on rain, dew or fog for whatever moisture they obtain. Consequently they must be types that tolerate a level of drought. Most of them can reduce their evaporating area and at the same time protect the growing point of the plant by the rolling or curving in of the leaves when they begin to dry. When the plants are moistened, even after many years of drought (for instance in your moss packet), the leaves swell, become green and spread out again. Practical advantage of this can be taken in two ways when collecting: firstly, moistening these bryophytes often results in a very rapid uncurling which aids identification; secondly, during and after rain, the drought-resistant bryophytes become green and conspicuous: mosses suddenly appear prominently on rocks, walls and trees which previously seemed free of them.

Light can be limiting in lowland tropical moist forest, where only about 2% of the light at the canopy reaches the forest floor. It is also important in its relation to evaporation, and bryophytes in bright places are likely to be drought-resistant, unless growing in permanently damp or wet places. Although some live in very low light intensities (e.g. in caves), light is still necessary for photosynthesis.

Altitude is an important factor in determining the distribution of bryophytes as well as other plants, as you can see as you ascend a mountain. In the tropics, bryophytes are always more abundant and varied in mountainous areas, particularly above 1000m-1500m, and in the 'mossy' forests (2000m-2500m). The effect of altitude is complex, and includes amongst others: changes in humidity, more rapid radiation of heat, decrease in average temperature, decrease in atmospheric pressure, and increase in ultraviolet radiation. Depending on the physiology of particular plants one or more of these factors will apply more decisively in controlling distribution. Many mosses of high, exposed places are tinged with red, purple or brown.

5. How to collect

A simple rule for collecting is to assume that if two plants look different they are different; it is better to collect one species several times than to pass over a related species entirely - and the range of variation may in itself be a very valuable addition to a herbarium. Some species grow intermingled, especially liverworts, and are difficult or impossible to distinguish with a hand lens. It is also the case that bryophytes often have very strict ecological and habitat preferences, and

apparently similar plants in different habitats may well be different species. So use your instinct and rely on a plant's "look" - a distillation of all of its characteristics: colour, size, manner of growth, shape of leaf, branching, habitat and so on. You will notice that experienced bryologists usually have a good idea what a plant is before they look through their hand lens - and part of this skill is purely observational, based on a knowledge of variation amongst bryophyte taxa. Once you have "got your eye in" you will find this an invaluable skill.

In temperate climates, most bryophytes that produce sporophytes do so in spring or late summer to autumn, but in more equable tropical climates sporophytes can be seen throughout the year, although each species has its own season. Sporophytes are often useful or even essential for identification, and they should therefore be searched for and collected, notably in the Meteoriaceae, which fruit very sparingly, so any fruiting stems should be picked out and packeted separately. Nevertheless, do not neglect to collect a specimen merely because you cannot see a sporophyte. The type of male and female sex organs is sometimes crucial for identification, so look for these also.

You should also make sure you collect the whole plant. Many tropical epiphytic mosses have conspicuous, pendant secondary stems, and inconspicuous primary stems running along the bark. The latter may be vital for identification of the material.

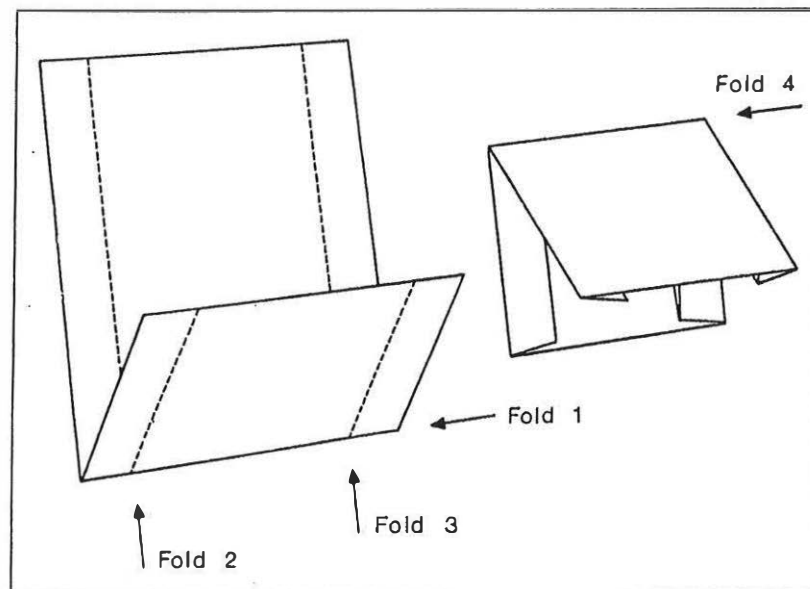
Some parts of the identification process are easier with fresh material, so even if you don't know the identity of a plant, it will still be useful to look for sporophytes or perianths in the field. With hepatics, it may be essential to look for oil bodies and to measure, count and describe them before they disappear on drying. This of course presumes the availability of a microscope in the field. (Sometimes the local herbarium, field station or botanical laboratory may be able to provide a microscope.) If you do this, keep the shoot that was studied separate in a small packet within the main packet. (This will guard against the problems associated with a mixed collection.)

Having found your bryophyte, there is no one way to deal with it - different collectors favour different methods. It is necessary first to collect and packet it in some way and to record collection information, then dry it (and keep it dry) before packing it to take away. This topic is covered from a professional herbarium viewpoint in Fosberg and Sachet (1965)

5.1 Equipment The most important items of collecting equipment are a hand lens, a knife a pencil or waterproof marker, and packets. The hand lens ideally should have a magnification of x20 with a fairly wide field of view, but this may not admit enough light in forests, so

also take a x10 or x12. (You may find in a moist forest that your lens is of little use, being constantly misted up.) Always have your lenses tied round your neck. Even then it is possible to lose them, so take a spare (as it may be impossible to buy another one locally). The knife should be sharp and is needed for scraping off or digging up your specimen; it may also be required to cut off pieces of bark, and scrape the surface of soft rock. For entering virgin forest a machete (large knife) may be needed, unless you go with a guide. These can usually be bought locally very cheaply.

5.2 Packeting. Supplies of paper for packets is a very important detail, which should not be left to chance. One way is to packet your collections in envelopes made on the spot from local newspapers, collection data being written on the envelope in water-insoluble ink. Unfortunately, newspapers can be difficult to obtain in some countries, and expensive to buy, and in this case it may be much better to take thin paper along, such as old computer paper. Strong brown paper bags (as used for vegetables) are another option, but not if the bryophytes are wet and the gum holding the bags together is water-soluble. If the mosses are very wet, gently compress them to remove most of the water, and pack in double or treble thickness packets. This method is described in use in Cameroun by Edwards (1986). Wet paper will disintegrate if not handled carefully, so carry wet packets with care in the field and try to dry them as soon as possible, or transfer the bryophytes to dry packets at the end of the day. The packets should be about 12cm x 8cm (about the size of 3in x 5in index cards), and can be folded as follows:



Any particularly small specimens should be wrapped in an appropriately sized piece of paper before being put in a normal size packet. This also applies to sporophytes or fertile parts of plants where these are in short supply, and have been isolated in the field - but always keep them attached to part of the gametophyte to avoid later confusion.

Earlier collectors used cloth bags (10cm x 20cm), with collection data written on the outside in black lead pencil or indelible pencil, or on a slip of paper inside. A dozen or so of the smaller bags are then put into a larger cloth sack, such as a 10 kilo flour or sugar sack, but this would now probably be regarded as unacceptable because the collections would get badly mixed. The tendency now is to packet species separately as much as possible. This can however be time consuming, and perhaps also difficult and inconvenient if the weather or light is bad, but is probably easier in the field when the material is still fresh than when jumbled together in the packet later. Generally, though, it is best to maximise your collecting time, and sort and document your specimens at the end of the day. You must use your common sense - after reading this guide you should be able to recognise good practice, so you must balance expediency with the scientific value of your collection.

Some bryophytes growing on soil are only very loosely attached to the substrate, for example in marshy areas, but others may be very closely adhering, and can only be removed with a piece of soil. As the collection dries, this will turn into dust, and produce a fine powder to decorate your herbarium whenever you open the packet. The plants are apt to break up if separated too roughly from fresh soil, so one strategy is to wash off excess soil gently at the earliest opportunity - although this may well also wash away any gemmae etc. if the washing is too vigorous. It is probably best to pare away as much surplus earth as possible from beneath the crust without breaking up the specimen, and packet in stiff paper, possibly using double packeting. Avoid bending the packet, but press lightly. Liverwort thalli in particular are prone to break into bits when the crust on which they are growing cracks.

Try to avoid the use of plastic bags for collecting, as they make it difficult to get the specimens dry; species can get very mixed up over a period of time; plants are likely to go mouldy or etiolated; they are more difficult to label properly. Plastic bags are acceptable only if you are going to transfer the specimens to paper packets within 24 hours, but this is not always easy to do if you have collected a lot, or if the weather slows down the processing of your day's specimens. Plastic bags are likely to be less of a problem in the cool mountains than in the hot lowlands - but they may force ripe hepatic sporophytes to shoot within a day.

One circumstance where you will need to use plastic is if you are bringing live bryophytes back home, although you are likely to need a permit for this. You should use very sturdy bags, not the thin sort that tend to stick to the plant. Remove most of the moisture from the plants (squeeze them out) and there must be some air in the bag. Keep them as cool as possible e.g. by using a hotel room refrigerator, and reduce the time kept in plastic, for instance by collecting them the day before departure.

5.3 *How much to collect.* This can be an emotive issue. In the past, large quantities were collected, but today's more conservation-minded approach suggests that you should collect more modest quantities - enough to fill a 12cm x 8cm packet should be plenty for one collection. (This packet size is only approximate - choose a size that fits the way you wish to store them.) However, you may find that you will need more than one collection of a specimen, for:

- your own herbarium
- the local herbarium, so they have samples of everything that you collect (in some countries this may be a prerequisite of any collecting trip, for instance in Brazil, but is in any case an essential courtesy)
- if you need to send the plant to an expert for identification, it is courteous to allow him to keep part or all of the specimen
- you may wish to have specimens to exchange with other bryologists (this is a recognised practice in botany - herbaria and collectors frequently swap specimens to help build up representative collections)
- a national herbarium

Sometimes it may only be possible to collect a small specimen, but remember that your collection won't be much use as a specimen if there is insufficient material to allow identification. Particularly for hepatics there are reasons why your collection should be more than just a few scraps:

- there may be a need to search a large amount of material in order to find the rare inflorescence, or the perfect peristome, or to get a feel for the amount of intracolonial variation - often very important with hepatics.
- the really important plant in a collection may not be what the collector saw, but some minute plant mixed with it. For a taxonomist working with such a collection it is maddening to have two stems of a possible new species, which are insufficient for adequate diagnosis. Similarly, what the collector thought was one species may be two or three that are difficult to

distinguish, and what appeared to be an adequate specimen may prove to be inadequate. This happens even with experienced collectors, for instance with the liverwort families Plagiochilaceae and Lejeuneaceae.

- if a plant is in any way unusual, it may be important to distribute samples to a much wider audience.

Nevertheless, even if you need five or six collections, do not over collect, in respect of the privilege of being allowed to collect, and in deference to the importance of the tropics in the ecology of the world. It is saddening to see torn tufts of moss hanging from trees and rocks following the depredations of the careless and wanton collector.

5.4 Labelling First of all, each packet should be uniquely identified, clearly and indelibly. Most collectors use sequential numbers for this. Many just start with collection number 1 and keep going, and this is perhaps the simplest and least confusing way. Others elaborate this slightly by adding a date or a site (e.g. 8806/1 or 880601/1 or site1/1 or a combination such as 88/site1/1) and so on, but it is important whatever method is used that mistakes in numbering do not occur - and mistakes are easy when writing hurriedly and in bad conditions, and especially when different nationalities are involved in the expedition. Pre-printed collecting notebooks with tear-off labels make it easy to maintain the sequence accurately. The numbering scheme should also be versatile - you may have to add extra numbers later (for instance where one mixed collection yields several specimens). The ink from ball-point pens is liable to fade in the tropics, so use ordinary or indelible pencil or waterproof markers.

In field conditions, numbering sequences are not always easy to maintain (you may accidentally use the same number twice, for instance, or forget the last number you used), and you may in any case prefer to sort out packet numbering at the end of the day. In this case, temporary field numbers are best, such as taking the date and time from a watch and writing this on the packet, so that there is no chance of getting the packets out of sequence. (Incidentally, even supposedly waterproof watches seem to leak in the wet tropics, and it is best to use a fairly cheap watch in a polythene bag with silica gel crystals.) Another method is to use pre-numbered tickets, such as cloakroom tickets or menu pads, with the top copy going in the packet, the duplicate remaining as a record. It is also possible to write on many living phanerogam leaves with a ball-point pen or marker, for instance when collecting epiphylls.

If it is necessary to collect as much as possible in a limited time, you can put all specimens (packeted) from one habitat at one site in a

bag together, and label the bag - but this method is obviously error prone.

It will also be necessary to record the details needed for the final herbarium packet, where these are not constant for the site, or for the day, e.g. substrate (rotting log, rock etc.) and identity, even if only known to family level (this saves a lot of time later). The type of rock, soil or tree is also very important, if you can identify, or describe it. For epiphytic specimens, indicate the precise location on the host (e.g. height on a trunk, side of a branch) and the host species if known; for epiphylls, indicate the host species (again, if known, although this is often impossible), which side of the leaf, and so on. Deep or light shade could be added, colour when fresh (specimens may turn brown on drying). This information can be written directly on the packet, or preferably in a notebook, or better still spoken into a dictaphone, which is quicker but needs transcribing to a notebook at the end of the day; tapes should be kept as a back-up in case of loss/soaking of the field notebook. Remember spare tapes and batteries, and also Murphy's law - if a piece of equipment can go wrong, it will. If you don't have a dictaphone (or if it is affected by the humidity, or goes wrong), it is less tedious to write directly on the packet, and only use the notebook for less frequent notes, such as when you arrive at a new site or habitat, but this is also more risky as paper packets can disintegrate. If you make field identifications, always check them again at the end of the day, when you are under less pressure and have access to identification manuals. As it gets dark about 18.00hrs in the tropics, much packeting and documentation has to be done by artificial light. It is worthwhile taking a good lamp.

The general rule should be to document each specimen as fully as the collector is able. A few well-documented specimens may be much more useful than a mass of poorly documented ones.

Keep a notebook throughout your trip, and keep it up to date daily. If you are recording written data in the field, it is a good idea to use a different notebook in the field, as this may get wet or lost, and transfer data to your formal notebook at the end of each day. Provided it is not lost, the field notebook also provides a useful back-up to the formal notebook. This should contain details of all the places you visit - description, latitude and longitude or other map reference, altitude (**take an altimeter**) and so on, followed by the collection numbers for each site and habitat. You will need this information to write out the final packets, but also so that you can produce lists for the sites you visit and write an account of your trip.

Notebooks containing waterproof paper are available from Hawkins and

Manwaring, Westborough, Newark, Notts.

Make sure you have enough information to write (as a minimum) the following on a label:

- collection number
- date
- identification (even if only to a broad grouping)
- locality - description, latitude/longitude or grid reference
- habitat - aspect, substrate, vegetation type
- altitude (if possible)
- other observations - associated plants, whether fruiting, abundance or rarity etc.

In some places you may only have a large-scale map (if any), and it is then very desirable to draw detailed sketch maps of collecting locations, together with measured distances to landscape features. The description of each location should be sufficiently detailed that it can be refound, if necessary.

5.5 Drying Drying is essential, otherwise fungi will attack your collections. If you are in a dry area, it should be possible to air dry them over a few days (either spread in a single layer in the sun, or in your tent or room), but in a wet area, this may be a major problem and preoccupation. For those with an unlimited budget see Croat (1979) - take a pick-up truck with you, equipped with a professional herbarium drier heated by butane. More practical is some arrangement such as described in Frahm and Gradstein (1986), using a metal frame holding a wire mesh shelf, surrounded by a cotton curtain, and heated from below by one or two kerosene stoves. The apparatus weighs about 2.5 kg, but it is essential to have a reliable method of drying your specimens, otherwise, as Frahm and Gradstein point out, your specimens may become of more interest to a mycologist. (Do not use the strong heat used for vascular plants, unless you hang the bryophytes above the frame. 'Cooking' bryophytes will distort cell structures, preventing reconstitution on re-wetting and use in later growth studies.) Another alternative is to use net shopping or vegetable bags, hung up over heaters or on a line in the sun. Don't use a heavy plant press, as this can damage sporophytes and some critical morphological features of the specimen, although leaves with epiphylls should be pressed lightly when drying to keep them flat, as should very large 'hanging' moss (Meteoriaceae etc.). Use dry paper in this process, such as botanical drying paper, or thick wads of newspaper, and change daily until dry and don't mix with bulky flowering plants. The most comfortable method, especially in the humid tropics, is to hire an air-conditioned hotel room - your specimens, if laid out in a single layer, should be dry within 24 hours.

Delicate hepatics in particular will blacken with collapse of tissue if they are not dried carefully, and cells that have collapsed in this way do not recover when soaked. This can be a real difficulty with epiphylls, when the phanerogam leaf dries slowly, and prevents the hepatic from drying. A thin press, mentioned above, is the only solution. Gentle pressing can also be an advantage with some thallose hepatics, but heavy pressing and roasting can make it impossible to recover the original cross-section.

In summary, dry as quickly as possible, at as low a temperature as possible.

5.6 *Keeping them dry* When specimens are thoroughly dried, they should be placed carefully in polythene bags to prevent them from picking up moisture from the air again. It is a good idea to bundle packets together with elastic bands (about 10-12 per bundle) for ease of handling. Greene (1986) recommends adding activated crystals of silica gel to the plastic bags, which are brought into the field in cotton bags, dried with the specimens and then put in one or two paper packets at the top of each bag. This also makes sure that any moisture that might get into the bag due to incomplete sealing or drying will be adsorbed by the crystals and not the bryophytes. Mothballs are equally useful. Sturdy bags should be used to provide protection during transport. The bags should be sealed tightly with sticky tape. Keep a close watch on the sealed bags, and open immediately any showing condensation, and re-dry the packets. A little dichlorobenzene amongst the packets will deter cockroaches and other pests, if the collection is to be stored for some time. Always pack the notebook separately from the specimens.

5.7 *Packing for transport* The physical volume of bryophytes that you collect may be surprisingly large, and you should think about how you are going to get them home before you start collecting. The stages will be:

- pack them carefully (see 'Keeping them dry' above) and tightly to avoid shaking about during transport.
- be able to carry them to wherever they are to be despatched from (which means if you are backpacking you may need to make periodic trips back to a post office).
- make arrangements to pack them properly - preferably in wooden crates (such as tea chests) that do not allow the plastic bags to be damaged, or in strong cardboard boxes, preferably with strengthened corners.
- be aware of the official requirements for custom declarations, and the local regulations for the export of plants, if they are to be sent directly back home. See 'Customs' below. Dried

- plants can be regarded for customs purposes as technically dead.
- have enough money to pay for the crates and the postage.
- agree with the local herbarium whether you will return duplicate specimens from home following identification, or whether you will send the specimens straight to the herbarium, and send a list later. Send them from home if at all possible, so you can be absolutely sure what is in the packet (see 5.9 below).
- don't expect the crates to get home for several weeks or possibly months.

5.8 Customs It may be necessary to get written permission to export specimens from the host country. This can sometimes be counter-productive, and local advice should be sought. If you have made contact with a local herbarium, this will solve many of the problems, as they may be able to help with the transport back home, and will be aware of how to deal with customs, postal services, etc. – but don't expect this sort of help to be available unless you have arranged it specifically in advance. For entry into the UK, herbaria here have special Customs 'Privilege Labels' to avoid import problems. These are especially useful if specimens are to be posted. Customs are increasingly opening such packages if not so labelled and can damage specimens. Discuss this with your local herbarium. See note in para. 2.1 about dealing with officialdom.

5.9 When you get home Once you get them home, you will need to transfer them to permanent packets, either as you identify them, or perhaps as a one-off exercise when you get back to check that they have all arrived safely. The danger is that packets and collection data become separated, which is particularly likely if collections remain unsorted. It is important to sort, re-packet, fully label (typed labels and photocopied duplicates) and split into sets for different herbaria. If a specimen is correctly labelled it does not matter if it remains unidentified for years. Sorting if possible should be done by the specialist who is studying the collection. Separation into duplicates before this has been done is risky, as it may remove evidence of plant associates, and also the ability to search through the material for some taxonomically important component.

5.10 Photography Don't underestimate the value of photography in collecting, both for general habitat views and for individual plant studies. A great deal of skill is necessary for close-up studies of bryophytes, but Edwards (1986) discusses some of the problems of photographing bryophytes in the tropics, and provides useful advice on equipment, magnifications etc. The camera will provide a valuable record, and should be used as a supplement to your other methods of recording information. An Eastman Kodak publication on tropical photography (1986) is included as an appendix in Chapman (1988).

6. Suggested research topics

Although the purpose of this guide is to assist collecting, there may also be opportunity for other types of research.

6.1 *Floristics* Producing a list of collections is useful in itself, and may merit publication. This will publicise the material for possible use by others, and may add significantly to our knowledge of phytogeography.

6.2 *Taxonomic revisions* It will quickly become apparent while trying to identify tropical bryophytes how difficult this is, and the great need for regional and world-wide revisions. The latter will often be a very big undertaking, requiring access to a good library, a rich herbarium, and especially access to a loan facility for borrowing material, particularly type specimens. Nevertheless, concentrating your collections on one particular group or genus may provide the foundation for a contribution to such a revision.

6.3 *Ecology* Taxonomic knowledge is a prerequisite for ecological work. There are many possibilities here, and you will either need to have a very good idea in advance about what you are going to do, or have someone on the expedition who is able to give support and advice. You will need to take any equipment you need with you: it is unlikely to be easily available at your destination. Possible areas of investigation are:

- what grows in/at a given area, altitude, habitat, tree, etc.
- what habitats are occupied by a given species or genus
- estimates of bryomass at different sites or altitudes

6.4 *Reproductive biology*

- distribution of sporophytes of a given species in different habitats
- characteristics of sporophyte production between different species in the same habitat
- seasonal distribution of sporophytes (difficult unless you are there long enough)

7. How to distinguish between different bryophytes

Many hints have been provided already on how to distinguish tropical bryophytes sufficiently well to be able to predict the value of collecting them. There are some characteristics of bryophytes that have

more importance and significance for identification in the tropics than in temperate regions, and vice versa, but a separate paper is planned on this, and so it is not dealt with here. Although you should use the sources mentioned in the 'Literature on identification' section below as a source of information before you go, only collecting in the field, and work at the end of the day on identifying your collections, will give you a feel for this.

8. Literature on identification

You may not find it easy to find books ('floras') to help with the identification of your bryophyte collection. There are not even lists of known bryophytes for many tropical countries. This position is slowly changing, despite the present lack of knowledge about the tropics. Some areas have been worked much better than others, particularly the richer floras such as those of the Caribbean and South East Asia. Floras covering quite wide areas are now becoming available, for instance Eddy (1988) covers the mosses of the whole of S.E. Asia, and Bartram (1949) is still the most useful book for the mosses of Central America. For the liverworts of tropical America, Gradstein's key for Puerto Rico (Gradstein, 1989) can be used. In other parts of the tropics the position is not as good, but there are projects underway or being considered in most of the tropics, although they may take many years to complete. A very useful general survey of available literature for both individual countries and for genera (Greene and Harrington, 1988, 1989) is now available. These documents should give you pointers to the more general papers on the country in which you are interested. It may still be necessary to chase up references to more detailed, local papers, and the British Museum (Natural History) Botany Library may be able to provide you with photocopies (see below for details). At a higher level, you will find Schofield (1985) very useful for deciding to which group a plant belongs, and there are also generic floras for some parts of the world. Look through the bibliography for these and other books that cover your area. There are much fewer books on liverworts and hornworts than there are for mosses.

If there is no local flora in existence, you may be venturing into the area of taxonomic research. It will be then that you benefit from the quality and frequency of your collections, both to get a picture of the variability of the taxa, and also to search for perianths, peristomes, etc., which may be necessary for identification and study.

At a major library such as the British Museum (Natural History), you will find several journals concerned with bryology, such as *Journal of Bryology*, *Lindbergia*, *Journal of the Hattori Botanical Laboratory*, *The Bryologist* and *Cryptogamie*, as well as many journals devoted to particular areas of the tropics. These will often give leads to useful

papers about the area you are visiting.

9. Acknowledgements

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10. Bibliography

The following bibliography contains references to publications some of which you may find it difficult to locate. The British Museum (Natural History) may be able to provide (quite expensive) photocopies of some of the scientific articles (contact the Library on 01-938 9123), but copies of most items are held by (or have been seen by) the author of this guide, who will be willing to help where possible.

Where prices are quoted, these are as at June 1988 or later.

Abeywickrama, B.A. (1960). The genera of mosses of Ceylon. *Ceylon J. Sci. (Bio. Sci.)* 3(1):42-122. [Like other generic keys (e.g. Griffin and Morales (1983), Van der Wijk (1958), Van der Wijk and Chopra (1966)), this is not easy to use, as it requires knowledge of 'phylogenetic' characters that are often difficult to observe.]

Ando, H and A. Matsuo. (1984). Applied Bryology. *Advances in Bryology*: 2. J. Cramer. [Covers all known uses and potential uses of bryophytes, including medical, ecological (both as erosion controllers and bioindicators) and biochemical.]

Bartram, E.B. (1939). Mosses of the Philippines. *Philipp. J. Sci.* 68. Reprint Hbk:DM135. [A useful book for Malaysia as well as the Philippines. The recent reprint is unfortunately very expensive.]

Bartram, E.B. (1949). Mosses of Guatemala. *Fieldiana: Botany* 25. Chicago Natural History Museum. [A useful book for all parts of tropical America, well-written and easy to use, with good keys, descriptions and illustrations. Still available quite cheaply via the Missouri Botanical Garden, although the nomenclature is somewhat outdated.]

Blashford-Snell, J. and Ballantyne, A. (1977). Expeditions, the Experts' Way. London. [A standard 'how to do it' book.]

Breen R.S. (1963). Mosses of Florida. University of Florida Press,

Gainesville. [Florida has a relatively small number of tropical mosses, but this book has good short descriptions and quite good illustrations of most of the common mosses of the Caribbean region.]

Brotherus, V. (1924). Musci (Laubmoose). In: Die natürlichen Pflanzenfamilien, Bd. 10, 11. Engelmann, Leipzig. Reprint, 1978: DM394. [A world-wide summary of all moss families and genera, with brief keys to species.]

Chapman, R. (1988). Tropical Forest Expedition Manual. (3rd ed.). Expedition Advisory Centre (1 Kensington Gore, London SW7 2AR). Pbk. £5. [The EAC is jointly administered by the Royal Geographical Society and the Young Explorer's Trust, and provide an information and training service. This manual is designed for those with limited expedition experience, who are intending to visit a relatively unexplored tropical rain forest area. It covers dress and equipment, movement and navigation, camping and cooking, local assistance, air supply, and some guidance on research topics, as well as appendices on photography and reference sources.]

Croat, T.B. (1979). Use of a portable propane gas oven for field drying plants. *Taxon* 28: 573-580. [Of more use to those with well-financed logistics.]

Crum, H.A. and Steere, W.C. (1957). Mosses of Puerto Rico and the Virgin Islands. *N.Y. Academy of Sciences* 7(4). [Useful for the Caribbean.]

Caulfield, C. (1985). In the Rainforest. Heinemann, London (Hbk:£10.95) and Pan (Pbk:£3.95). [A journalist's account of the nature and fate of tropical rainforest, with emphasis on man's assault on the forest; very well written, most informative, and hard-hitting. Like Myers, this provides plenty of evidence to justify a scientific expedition to the tropics.]

Davies, S.B. et al. (1986). Plants in danger : what do we know. IUCN (International Union for the Conservation of Nature and Natural Resources), Gland, Switzerland and Cambridge, U.K. Pbk:£15. [This is a mine of information on the flora and vegetation of each country in the world, as a background to conservation requirement, although bryophytes don't get a mention. It will provide a useful starting point for selecting a country and finding pointers to further information.]

Delgadillo M., C. (1987). Additional recommendations for bryologists visiting the tropics. *Taxon* 36: 289-291. [Particularly aimed at professional botanists, and their relations with tropical colleagues during visits, but of relevance to anyone who wants to collect. An addendum to Mori and Holm-Nielsen (1981).]

Eastman Kodak. (1986). Tropical Photography. Kodak Publication C-24. [Seven pages of advice on care of equipment and materials, exposures, processing and dealing with fungus. This item is also included as an Appendix to Chapman (1988).]

Eddy, A. (1988). A Handbook of Malesian Mosses Volume 1: Sphagnales to Dicranales. British Museum (Natural History). Pbk:£15. [The first of five parts. Indispensable, containing keys, descriptions, illustrations and habitat and distribution data.]

Edwards, S.R. (1986). Bryophyte collecting and plant photography. *University of Hull Department of Geography Miscellaneous Series* 30: 65-72; 102-108. 2 fig. [Describes collecting and photography in Cameroun.]

Fleischer, M. (1902-1922). Die Musci der Flora von Buitenzorg. 4 vols. E.J. Brill, Leiden. (Reprinted in two volumes, 1976. Hbk:DM400). [This is strictly speaking a moss flora of Java, but it covers a large part of the Eastern tropics and is (according to P.W. Richards) "by far the best tropical moss flora ever written, though now of course somewhat out of date".]

Florschütz, P.A. (1964). Musci of Suriname, Part 1. (Flora of Suriname, Vol. 6 Part 1). E.J. Brill, Leiden. Pbk:DM48. [This is one of the best tropical moss floras, and includes most of the acrocarpous mosses likely to be met with in the lowlands of the Guianas and Amazonia.]

Florschütz-De Waard, J. (1986). Musci, Part 2. (Flora of Suriname, Vol. 6 Part 1). Pbk:DM38. [Continuation of Florschütz (1964). Includes three families of pleurocarps, including Hookeriaceae.]

Frahm, J.-P. and Gradstein, S.R. (1986). An apparatus for drying bryophytes in the field. *Bryological Times* 38: 5. [Describes a home-made, portable aluminium frame with a wire mesh shelf, weighing 2.5 kg in total, heated with a kerosene stove, used in Borneo and South America.]

Gifford, N. (1983). Expeditions and Exploration. Macmillan, London. [A book with lots of lists (e.g. what to take, what to put in your medical kit etc.), and advice from those who have planned expeditions or gone on them. An extensive bibliography.]

Gradstein, S.R. (1989). A key to the Hepaticae and Anthocerotae of Puerto Rico and the Virgin Islands. *The Bryologist* 92(3): 329-348. [A key emphasising vegetative characters for 237 species in 92 genera of liverworts and hornworts recorded from Puerto Rico and the Virgin Islands; also useful for other parts of tropical America.]

Greene, S.W. (1986). Keeping them dry. *Bryological Times* 38:6.

[Describes how to keep dried specimens dry by adding silica gel to the polythene bags of dried specimens, on a trip to Chilean rain forests.]

Greene, S.W. and Harrington A.J. (1988). The Conspectus of Bryological Taxonomic Literature - 1: Index to monographs and regional reviews. (*Bryophytorum Bibliotheca* 35). J. Cramer in der Gebrüder Borntraeger Verlagsbuchhandlung, Berlin and Stuttgart. Pbk:DM120 [A world-wide list of taxonomic literature, presented alphabetically by genus and family.]

Greene, S.W. and Harrington A.J. (1989). The Conspectus of Bryological Taxonomic Literature - 2: Guide to national and regional literature. (*Bryophytorum Bibliotheca* 37). J. Cramer in der Gebrüder Borntraeger Verlagsbuchhandlung, Berlin and Stuttgart. Pbk:DM120 [The indispensable source for the main bryological literature of countries, regions and islands of the world.]

Griffin, D. and Morales, M.I. (1983). Keys to the genera of mosses from Costa Rica. *Brenesia* 21: 299-323. [Useful key to genera of Central America - over 200 genera are dealt with.]

Fosberg, F.R. and Sachet, M.-H. (1965). Manual for tropical herbaria. (*Regnum Vegetabile* 39). International Association of Plant Taxonomy, Utrecht. [A very detailed account of herbarium management in the tropics. Covers collecting and labelling as well as herbarium techniques, procedures and administration.]

Hatt, J. (1985). The Tropical Traveller. Pan, London. Pbk:£3.95. [Preparation, equipment, money problems, health, exploring, etc. A very cheap way to get a feel for the problems.]

Herzog, T. (1926). Geographie der Moose. G. Fischer, Jena. Reprinted 1975, DM120. [This is out of date, but is still a good introduction to floristics, including the tropics, for anyone who can read German.]

Jacobs, M. (1988). The Tropical Rain Forest. Springer-Verlag. Pbk:£20.65. [Original Dutch edition published 1981. A well presented and useful general book on the structure, ecology, physiology etc. of lowland tropical rain forests with an emphasis on S.E. Asia. This sort of book is essential as a source book for planning an educational expedition to such areas. It specifically excludes other tropical areas, including upland forests, where bryophytes are likely to be in greater abundance and variety.]

Long, D.G. (1982). Collection and preservation of bryophytes in Arabia. *Bull. Emirates N. H. Gp (Abu Dhabi)* 18: 18-19. [A brief guide to recognising bryophytes, collecting, packaging, drying and labelling.]

Longman, K.A. and Jenik, J. (1987). Tropical forest and its environment. 2nd ed. Longman, England. Hbk:£17.50 [Excellent account of rainforest ecology in a small comprehensive format; some emphasis on Africa.]

Mitchell, A.W. (1986). The Enchanted Canopy. Fontana/Collins. Pbk:£9.95. [Subtitled 'secrets from the rainforest roof'. Mainly describes animal life, and bryophytes don't get a mention, but lots of beautiful photographs.]

Mori, S.A. and Holm-Nielsen, L.B. (1981). Recommendations for botanists visiting neotropical countries. *Taxon* 30: 87-89. [Aimed at professional botanists, with the items of more general interest already mentioned in this guide. See also Delgadillo (1987) for elaboration of the more specifically bryological points.]

Myers, N. (1984). The Primary Source: Tropical Forests and our Future. Norton and Co. [An important and influential book about the importance of tropical forests to the world. The book contains all the information and arguments you will need to justify a trip to the tropics.]

O'Shea, B.J. (1985). Bryological Societies and Working Groups. *Bryological Times* 31: 7-8. [A list of all known bryological societies and working groups, giving basic information and contact points.]

Perry, D. (1986). Life Above the Jungle Floor. Simon and Schuster. [A popular account of a biologist's discoveries in the tree tops of a Costa Rican jungle, including creating a tree top platform and a network of ropes from which he hung to observe the wildlife.]

Pócs, T. (1982). Tropical forest bryophytes. In: A.J.E. Smith (ed.), Bryophyte Ecology. Pp. 59-104. Chapman and Hall, London (Hbk:£50). [This is an excellent account of tropical bryophyte ecology, that fills out the more general picture provided by Jacobs (1981) and Whitmore (1984). It gives some idea of what species can be expected in different habitats in different parts of the tropics. Along with Richards (1984), essential.]

Richards, P.W. (1952, 5th reprint with corrections 1975). The Tropical Rain Forest. Cambridge University Press. Hbk:£40; Pbk:£22.50. [The classic text - and written by a bryologist - but a more academic approach than Jacobs (1981); still indispensable.]

Richards, P.W. (1984). The ecology of tropical forest bryophytes. In: R.M. Schuster (ed.), New Manual of Bryology Vol. 2, pp. 1233-1270. Nichinan. [Complements Pócs (1982), based on wider geographical area, and with a more detailed review of epiphylls.]

Schofield, W.B. (1985). Collecting bryophytes and processing for study. Appendix A (pp 387-391) of Introduction to Bryology. Macmillan. Hbk:£35. [A useful general summary of where and when to collect, collecting tools and methods, observations on fresh material, labelling, packeting, filing and storage. The book itself is excellent, and particularly useful for the circumscriptions of each family, which may help in preliminary identifications.]

Smith, A.J.E. (1978). The Moss Flora of Britain and Ireland. Cambridge University Press. Pbk:£22.50. [The standard UK text on identifying mosses, covering the whole flora. See also Watson (1981).]

Steere, W.C. (1944). Instructions to naturalists in the Armed Forces for botanical field work: No. 3 The collecting of mosses and liverworts. *Supplement to Company D Newsletter*. 1-13. Company D, 3651 S.U. Department of Botany, University of Michigan, Ann Arbor, USA. [Covers how to collect, where to look, how to document etc. A previous (and quite successful) attempt to cover a similar area to that of this guide, but now out of date in its approach to collecting.]

ter Steege, H. and Cornelissen, J.H.C. (1988). Collecting and studying bryophytes in the canopy of standing rain forest trees. In J.M. Glime (ed.) Methods in Bryology, pp. 285-290. Hattori Botanical Laboratory, Nichinan. [Briefly reviews possible methods of tree climbing and gives details of the method the authors used in French Guiana - using various rope climbing techniques, which are described. Several bryophyte species new to Guyana were found in the canopy.]

Van der Wijk, R. (1958). Precursory studies on Malaysian Mosses II. A preliminary key to the moss genera. *Blumea* 9: 142-186. [Usefully generally for tropical Asia.]

Van der Wijk, R. and Chopra, R.S. (1966). A preliminary key to the genera of Indian mosses. *Res. Bull. Panjab Univ. (N.S.)* 17:149-191. [See comments on Abeywickrama (1960) regarding generic keys.]

Vitt, D.H., Gradstein S.R. and Iwatsuki Z. (1985). Compendium of Bryology. (*Bryophytorum Bibliotheca* Bd. 30). Verlag J. Cramer, Braunschweig. [A world listing of herbaria, collectors, bryologists and current research - based on data gathered in 1983-4.]

Walter, H. (1971). Ecology of tropical and subtropical vegetation. Ed. J. Burnett, Oliver and Boyd, Edinburgh. [This book deals with high mountains, savannas, deserts, etc., which are not dealt with in Jacobs, Richards and Whitmore.]

Watson, E.V. (1981). British Mosses and Liverworts. Cambridge University Press. Pbk:£27.50. [A less comprehensive text than Smith

(1978) for mosses (only abbreviated descriptions of the uncommon species), but includes liverworts (unlike Smith). Essential for the beginner who is serious about getting to know British bryophytes.]

Whitmore, T.C. (1984). Tropical Rain Forests of the Far East. (2nd ed.) Clarendon Press, Oxford. Pbk:£25; hbk:£50. [Of general, world-wide interest, despite the title. Rather more academic than Jacobs (1981), and more up to date on literature than Richards (1952).]

Whittier, H.O. (1976). Mosses of the Society Islands. University of Florida Presses, Gainesville. [Good for Pacific Island genera, even if the species are different.]

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