RAPID ASSESSMENT OF TROPICAL PLANT COMMUNITIES USING VARIABLE TRANSECTS:

an informal and practical guide.

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ABSTRACT

Most surveys of plant communities, floras, and botanical resources in tropical areas are not meeting the needs of conservation and management. This is in part because tropical plants are so diverse and difficult to identify, but also because random plant collecting and sampling vegetation with plots are methods inadequate to deal with the variance and habitat diversity that must be covered in a short time. We propose some fast and flexible methods using variable transects that are practical for comparing composition and diversity for many distinct habitats and classes of plants. The transects are based on numbers of individuals to be sampled rather than area, do not require precise measurements, and can be modified for use with forests, savannas, clonal plants, epiphytes, floating aquatics, etc. They allow investigators to make more samples and spend more time on identification of critical plants. They are suitable for use when a statistically rigorous sample is impossible, but a first approximation of the vegetation is needed.

INTRODUCTION

There are two urgent reasons to have faster methods for sampling plant communities:

1) More and more, ecologists and other biologists are being asked to "assess" the biological communities, floras and faunas, and biological resources of large tropical areas in a very short time. This is because decisions about the fate of large areas are usually made by governments, large funding agencies or foundations, or large corporations. And for reasons of politics, economics, or social pressures (all related) these institutions, without delay, need to make the decisions that include environmental considerations. Such considerations were always important, they were just ignored before. Now they want "instant" information and if we do not provide it, a misguided decision about the future of a large area will likely be made. They will not wait.

2) With growing awareness of human induced changes in the environment, the need for monitoring changes over time has become obvious. It was always important, just ignored. Biological monitoring is difficult and sometimes very expensive. Since you cannot monitor everything everywhere, to study long-term community changes you must decide on a limited number of sites to focus your attention. You must live with your selection for a long

time. Better make some good choices. Better get as much information as possible about the area as soon as possible unless you want to wait years before starting your monitoring. Once again, the need for "instant" information to make good choices. The funding agencies do not wait.

Rapid surveys of plants and vegetation are certainly not new. But the way they have been done often means that the results are of little use for conservation or management. What follows is a brief review of the usual process, with comments on failings and strengths.

Mapping:

The commonest approach to plant inventory has been first to map an area into different broad categories usually defined as vegetation types, habitats, life-zones, ecosystems or something similar. This is based on some sort of remote sensing, visual inspection, or imagination. Modern satellite images with appropriate spectral band-widths and taken at the appropriate season are by far the most practical way to distinguish different habitats. Having the images in hand is the best way to start an inventory. A low overflight and ground inspection -- both done by someone with experience -- are the next steps to making a useful map.

These ecological maps have two main limitations: they deceive one into thinking there are no other differences in the vegetation; and they deceive one into thinking there are always distinct boundaries. Our experience has shown that usually 20 % or more of the distinguishable plant communities on the ground are not distinguishable using the images. Also, most larger areas have many communities that grade into one another without perceptible discontinuity. Most current graphic information systems (GIS) are not designed to show gradients. Maybe those preparing the maps are aware of the gradients and the arbitrary decisions needed to map discrete units -- but the user usually is not. More advanced software may permit maps that are not overly simplistic.

Floristic Inventory:

An inventory of plant species of an area is usually a list of all the plants known to have been collected in that area. Even if by good fortune the area has already been well collected, the plant collectors do not include sufficiently precise information on the habitat or locality. This is because collectors must concentrate on searching for the reproductive parts of plants, and are usually unaware of all but the most obvious habitat differences, or forget them by the time they unload the bag back at camp. The most frequent collections are of plants that are easy to see and easy to collect, not the most abundant or most important. Sending a botanist out to collect the flora in each community will result in a list of only plants that happened to be reproductive at the time of collection, and sometimes only those less than 3 m high. The time needed to get specimens processed and identified is usually not included in the time allocated for the project. An inventory of plant species as a list is not the same as an inventory of plant species populations or plant resources. To do that requires sampling.

Visual Sampling:

At one extreme is sampling vegetation with your eyes. Either by flying over it or walking through it, and having a reasonable short-term memory, one can make crude verbal descriptions of the structure, composition, and variability of the vegetation. One can even make some crude numerical estimates, and make a crude map. It can be very fast -- much faster than sampling the same size area with plots or transects. Obviously, the quality of the results will depend on experience, visual abilities, knowledge of the flora, and the effort spent observing it. But it is data, and some data is certainly better than no data. It is repeatable and testable. The danger is in making conclusions or recommendations for which the data is inadequate or inappropriate -- but this is also true for plots or any other kind of sample. It is just much more difficult for anyone else to assess the quality of a sample done with the eyes alone.

Plot Sampling**:**
Gridded plots or transects -- of whatever size and shape -- are nice to have. They are quantitative and potentially rigorous statistically, which the purely visual approach is not. They are almost essential for long-term monitoring of vegetation. If well-marked, they allow you to locate the same plants after long intervals. Plots are also excellent for sampling vegetation. If enough of them are used and they are appropriately spread out, an inventory of their contents can give a very good measure of the structure, composition, and variability of the vegetation. The ideal is to have a large number of small plot samples throughout a large area.

But, plots are also a pain. There is usually never time to do enough of them. They require surveying and delimiting of subplots, marking of corners, etc., which is extremely time-consuming, especially in thick vegetation To set them up usually takes as long or longer than measuring their contents. If in addition precise measures are made of the diameter or other characteristics of each plant and a number tag put on each stem, the time spent on measurement is also much greater. Most plants at any given time are not in reproductive condition. This means that getting and finally identifying the specimens is also extremely difficult and time consuming. These drawbacks are usually accepted as a necessary part of doing plots.

Another problem with plots is that in most vegetation, there are many more small plants than large plants. In forests most plants are usually the juveniles of trees. The plants that make up the bulk of the forest -- the biomass, the primary production, the flowers, fruits and seeds -- receive the least attention. This includes the plants most likely to be of commercial interest and most likely to be significant to the local ecosystem. Most of the time invested in inventory and measurement is spent on juveniles or small adults, and on small species. For most species, juveniles are much more abundant than adults. Knowing the density of juveniles is only important to conservation if one understands the life history and dynamics of the species. The result is that most of the data from plots may be the least important for an inventory.

A third problem is that the density of plant stems may vary tremendously between plots, and that unless comparisons of density is the goal, comparisons of community characteristics such as species richness, diversity, and relative abundance will have to deal statistically with different sample sizes.

In actual practice most quick survey projects only have time to put in just one or a couple of plots or transects, and their placement is chosen mostly for convenience. The number of plots is usually grossly disproportionate to the scale of the area and heterogeneity of the vegetation. The value of being rigorously quantitative is lost because the samples are not sufficiently representative of the area as a whole.

Rapid Quantitative Sampling of Plant Communities Without Using Plots

It is necessary to find methods for sampling plant communities that are some sort of compromise: very fast and yet quantitative. The following is one proposed general method that addresses most of the needs described. It has been tested in lowland terra firme in Peru, floodplain in Guyana, the mountains of Panama, successional stages of floodplain and mountains in Papua New Guinea, dry forest and savannah in Bolivia, palmetto hammocks in Florida, and the Forest Reserves of Chicago. The method is described here with a broad but college-educated audience in mind, from local tropical field biologists without advanced training to bio-mathematicians and statisticians --in hopes that this will provoke them to come up with something better and yet still practical. There are certainly other possible methods. Students of plant communities are encouraged to develop and test other ways of sampling that might be even more efficient or more appropriate for different aspects of the vegetation.

The Variable Transect Method: A sample of individuals rather than area.

The basis of the variable transect method is to sample a standard number of plants at every location, rather than a standard area. The second important aspect is that one does not make precise measurements. The advantages are a great increase in speed, a great reduction in equipment, supplies, and labor needed, and the opportunity to devote more time to identifying the plants (the major problem in the tropics), and more emphasis to large trees or frequently ignored life-forms such as herbs. The increase in speed of course means that many more samples can be made, which gives a great statistical advantage. Or, the scope of the study can be broadened since more habitats can be sampled in a given area, or less time can be spent in one area and more spent sampling other areas. There are also the statistical advantages to having equal sample numbers, and there is no assumption that species are randomly distributed -- since they are certainly not.

The method is variable in more ways than one. The length and width of the transect is always variable according to what area it takes to encounter a certain number of individuals. But one can also easily change the number of plants per sample, the number of classes of plants, the kinds of classes, the shape of the transect, the orientation of the transect with respect to the shape or scale of habitat or topographic variation, etc. These are all optional and depend on the decision of the investigator. Having all these options does put a burden on the investigator. It requires intelligent and practical choices, not just following a cookbook recipe.

The advantage of this method in addition to speed is that it is very flexible and can be changed to accommodate needs for a given area, a given vegetation type, or a given time schedule. For specific needs one can decide how consistent and comparable the samples should be. These transects are not intended for global standardized comparisons. Perhaps they could be used that way if a standard could be agreed upon for different kinds of vegetation. Certainly much of the plot and fixed transect data that already exists in the world can be converted to a comparable form by picking out of the data a standard number of individuals in a way that mimics a variable transect. Although they might be useful for first approximation comparison on a more global level, the principal value of the transects is comparison and description within a small region or area -- the scale that most conservation and management decisions are being made.

Limitations:

The sacrifices of not using an area-based sample can be the absence of data to calculate densities, the ratio of adults to juveniles, the ratio of trees to shrubs, or other similar structural data. These disadvantages are not terribly serious if the main purpose of the sample is to get the forest composition: the relative abundance of species within and between habitats and life forms, and the relative richness of plant species between habitats. Actually it is not terribly difficult to get density data while using this method -- one only has to make some simple measure of the area covered while sampling the requisite number of plants.

Since most static vegetation data is presented and analyzed by size-classes or life-form class anyway, the sacrifice of not using separate measurements of each individual plant is not that great. It is only that one cannot calculate basal area or similar measures of structure, though these might not be too difficult to estimate from the data. When individual plant parameters are considered sufficiently important, a solution is to make quick measures or estimates of each diameter or other measure of size. Precise measurements of size are most needed in permanent samples in which growth is measured, which these transects are not. The importance of precise measurements of distance must be weighed against the importance of variation in the vegetation. In most vegetation, the variation from place to place is so great that errors in distance measurement are utterly trivial and irrelevant to the data and conclusions.

When assessing where to cut corners, one must always come back to the question of what the data is to be used for, and how to get it most efficiently.

Details of the method and practical suggestions.

The method is essentially to walk down the middle of an unmarked transect and quickly registering and identifying a standard number of plants of any class (size-class or life-form).

<u>Where</u>:Habitat types are usually determined beforehand in the manner described above. It is expected that additional information acquired during the inventory will lead to modification of these categories. But unless you use a lot of them, the transects themselves will not allow you to map the vegetation. Rather, they are to be used to describe the composition and diversity of the different habitats in an area or region. This implies that you can already distinguish different habitats in the area before you start. If so, go into the area, find the habitat, get some idea of its distribution (i.e. its size and shape) and start sampling. If you are severely limited by time, first put a transect in what seems to be the center of the commonest or otherwise most important vegetation. Or, run a transect that cuts across as many habitats as possible (e.g. deliberately keeping perpendicular across a series of habitats, such as in a low ridge and ravine complex) -- making a note in your data when you change habitats.

If in doubt about habitats, use the following guidelines. Sample hilltops, slopes, and valley bottoms, as three different habitats. Look for major differences in soil or bedrock and sample on those. In mountains, sample at least once every 500m of elevation. If there is a regular cloud layer at a certain elevation, especially in the dry season, sample at that elevation. On floodplains, if there are different terraces or mounds and depressions, sample those. If there are no discontinuous habitats, just a series of gradients, sample at either extreme and in the middle. If there are successional sequences, sample different stages. If there are areas with periodic burning, flooding, or heavier animal grazing, sample those. If there are areas that receive more or less hours of sunlight, sample those. Any vegetation that looks different -- sample it. That ought to keep you busy getting useful information. More than likely you will discover some habitats or gradients that were previously unrecognized.

To ensure breadth of representation, sample sites are ideally chosen in a stratified-random manner within each general habitat type. But accessibility and time limitations will probably end up being more important factors than true randomness in site selection on the ground. The more samples the better, and the more widespread the better, especially for habitats covering large areas. If the habitat is highly diverse and variable it may take a large number of samples to accurately estimate the total species richness, but a few samples are usually enough to indicate comparative local richness of different habitats. If many habitats must be covered in a short time, then sometimes only one transect per habitat may have to suffice. Site locations can be described in some detail using maps, compass direction, and, when possible, co-ordinates using a GPS device. The ideal is that someone else would be able to relocate the transect site to within a few-hundred meters of where it was actually done.

Classes of plants: Any life-form or size range of plants can be considered a separate class. Classes could be taxonomic as well, for example a single family e.g. the palms, may be of special interest, or in the extreme, even a single species can be considered a separate class. In forest vegetation, free-standing woody plants are traditionally placed in the classes of: canopy tree layer, understory tree layer, and shrub layer. In tropical forests a class of trees 30 cm diameter and greater usually includes all canopy trees. In a forest with emergent trees, it would be useful to note which trees are over 100 cm diam. And in a forest with a high density of emergents (e.g. a Sequoia forest or large Dipterocarp forest), larger size-classes would be appropriate.

Usually a medium size class of trees 10 to 30cm diam. would include most of the understory layer; and a small class 1 to 10cm diam. would include most shrubs and treelets. Splitting the medium class into 10 to 20cm and 20 to 30cm classes is certainly possible even if the increase in information in doing so is not great. Splitting the small class to create a 1-2.5 cm or 1-5 cm class might make more ecological sense. Creating doubling size classes based on 1, 2, 4, 8, 16, 32, and 64 cm would probably make the most ecological sense, but has some limitations of practicality and the difficulty of comparisons with most existing data.

With a little practice, the great majority of woody stems can be rapidly placed by eye into the appropriate diameter size class. This saves lots of time. When the size class is in doubt for the borderline cases, holding a ruler up to the stem can be a quick substitute for using a special diameter tape. The number of plants likely to be misplaced in the wrong class is usually trivial.

In savannahs, shrublands, elfin woodlands, etc., different size classes of woody plants will be more appropriate, even if the concept of canopy and understory still applies. Trying to sample savannah trees using a 10 cm minimum diam. will produce a very distorted picture of the vegetation if nearly all of the trees are 5-9 cm diam. and none are over 12 cm.

For studies of trees as resources to animals it may be more important to know crown diameters of trees rather than stem diameters. The variable transect method could be modified to include quick estimates of crown diameters of each tree stem, or the classes themselves could be based on crown diameter. Since stem diameters are a crude estimator of crown diameters it is probably much faster to just measure the stems, but keep in mind that the results are less than accurate because of the variance between different species and different age-classes in the stem-to-crown relationship.

Clones, juveniles, and vegetation aggregates: Working with terrestrial plants less than 1cm diam (at 1.3m height from the base), or with lianas, epiphytes, or aquatics, etc. may require unique solutions (or they can be ignored). This applies equally to both plot and plotless methods. The main problem is that from natural cloning of stems it can be difficult or impossible to distinguish where one individual ends and another begins. Another problem with small plants is that there may be serious difficulties in identification of the early juvenile stages of both woody plants and herbs.

A solution to problems with clones in these life-form classes is to include area-based samples within the variable transect. For example, to count only presence or absence of species, not individual stems, in standard area segments along the transect (i.e. frequency) until the standard number of "individuals" is obtained. The standard area unit could be a size thought to approximate that of an average clone, or small enough so that the number of "individuals" is a good estimator of area covered by the different species. For aquatic vegetation the sampling can be done by paddling a boat in straight transect lines, sampling standard area units in the water and perhaps separating floating vs. submerged classes. In either terrestrial or aquatic systems, if relative species cover is the only goal, not a diversity index, one can estimate % area covered by each species in defined segments along the transect without making any attempt to have a standard number.

Lianas are especially challenging. Lianas that stick tightly to the trunks of host trees should probably be sampled separately (like epiphytes) from those that are free-climbing Stem size is probably even a worse estimator of canopy size for free-climbing lianas than it is for trees. Because of cloning from both the original base and from rerooting of fallen liana branches, clone size becomes much more difficult to estimate. Using a standard number of stem counts in a couple of size classes, or presence of a species in standard-area-unit samples (i.e. treating canopy-cover in the same way as ground-cover) might give a fair picture of the relative importance of different liana species. But a good comparable sample of liana diversity might require a much larger area of sample or many more stems than is needed for trees. Since there are no large mapped plots with all the lianas mapped, we do not yet have a good basis for resolving what methods of sampling and what classes are best to answer different questions of conservation importance.

The problem with juveniles, is difficult to solve. If one knows the plants well before starting, decisions can be made to, for example: count only true herbs thought to be adult, count only freestanding woody species, count everything except first-year seedlings, etc. Otherwise one must use strict morphological criteria such as: only herbaceous plants, or only woody plants (assuming one can distinguish the two) with stems more than 20cm tall; etc. Sometimes the dominant understory herbaceous vegetation (esp. some ferns) can be species that only reach maturity as trunk-climbers. One should make a decision about such cases before beginning the transect.

Vegetation or plant classes which occur in discrete aggregates (such as epiphytes on trees or the clumps of species associated with ant and termite mounds in savannahs) are most easily sampled in regular units (i.e. as vegetation aggregates rather than area units). The units can be individual trees, or individual termite mounds, etc. Each species can be registered only once per unit -- all other stems of the species in the unit considered part of the same clone. For the species richness and abundance measures one still stops after a determined number of individuals is reached, even if in the middle of an aggregate. The number of species per aggregate and the number of aggregates per species and per unit area are also possible to calculate.

For epiphytes it must also be remembered that one is dealing with 3-dimensional space and not just the ground, and a decision must be made whether or not to divide or limit the vertical dimension or diameter of the host stem or branch. One example, already used in a cloud forest, was to sample only the trunk epiphytes up to 3 m high on 100 trees, registering each species only once per tree. This was a standard number of samples (the trunks) varying somewhat in area, and with all the plants of one species on one trunk considered a clone. But it also could have been done as a standard number of epiphyte "individuals" as described above, stopping the samples as soon as that number was reached regardless of how many trees had been checked.

Whatever the class of plants, if it is especially important, diverse, or interesting, more transect samples of individuals or units can be made and more detailed information can be gathered than for the other classes. For example, more detailed information on the population structure of epiphytes *within* trees could be obtained if one took more time and effort with each tree. One just has to remember the difference in the kind of sample when making comparisons with other classes of plants.

Number of plants**:** For most tropical forests one person can usually check 300 - 400 plants in one day. The main variable in time is the speed of field identification or speed of collecting vouchers for identification. The question then is how to apportion the number of plants among samples or among classes. Statistically, more small samples will always be better than few big ones. The practical disadvantage is that it is time-consuming to make separate samples in many different places and much easier to stay in one small area or just continue one long transect.

The optimal compromise may be different for each situation. We have found that 50 plants per class in each sample usually allows us to do two samples per day of 3 to 4 classes each, or six to eight samples of just one class. For the class of canopy trees (i.e. >30 cm dbh), of which there are usually near 100 individuals in a hectare in lowland tropical forests -- and assuming that one could already recognize about half of them easily when the sampling is begun -- this means one could sample the equivalent of 3 to 4 hectares of trees in a single day. Clearly the more species that one can easily recognize, the more samples can be made. Methods for improving recognition are discussed below.

Width of transect**:** Deciding on the width requires considerable deliberation, especially when comparing different plant classes along the same transect (next section). Width is inversely proportional to length in a variable transect. A wider transect will be shorter, a narrower one longer. There are pros and cons to different width to length ratios. Since most species in tropical forests have clumped distributions at the scale of one hectare or smaller, there is high probability that a wide - short transect will include a clump of one or more species. While this may not seriously affect measures of species richness, it can seriously affect estimates of relative abundance. A nearby sample may have very different composition even if the diversity is the same and the species present are the same. A narrow-long transect is more likely to escape single species clumps and give less importance to them since it will cover more of the variation. Secondly, a very wide transect makes it more difficult to orient oneself, difficult to efficiently inventory plants, and difficult to estimate area, without some kind of grid system -- and that takes time.

On the other hand, narrow-long transects are more likely, if one is not careful, to extend into or cross over different habitats with different floras, and they take one far away from the starting point which can be logistically troublesome. The narrower the transect with respect to the size of the plants, the more precise the width must be. There is much greater potential for bias in bending the line slightly to include or exclude plants ("edge effect"). Making straight lines takes time. If, in the extreme, one uses a single, dimensionless, line-intercept method for large trees, the line must be perfectly straight. Narrow-long transects also exaggerate estimates of diversity when compared with square (or round) samples, though the increase in species richness of trees from a width to length ratio of 1 to 1 to that of 1 to 25 is only about 10% (based on data from Barro Colorado Island in Panama).

A compromise width must be chosen that accommodates these different theoretical and practical considerations. For canopy and medium-size trees (> 30 cm dbh) in lowland forest, we have found a transect width of 20m to be convenient since one can usually see all the trees over that width while standing on the center line. If one is accustomed to working in plots, 20m is also easy to estimate. It does not usually go longer than 500 m to sample 100 canopy trees. In dense cloud forests, a width of 10m, 5m, or even 2m may be more appropriate to sample trees. If one is doing a tree transect of the Amazon or Congo basin, 1m width might be better (i.e. 10 canopy trees per km) if one can keep a straight line.

For the medium-size trees (10-30 cm dbh), we have found that 20, 15, or 10 m wide may be convenient, and for the shrubs and treelets (1-10 cm dbh) and for herbs, usually 2 or 1 m wide. If the understory is virtually empty because of grazing, shade, or fire, obviously a greater width is appropriate. The width of the transect is measured by eye, (with occasional checks by pacing or other measurement), and is thus fast though not precise -- and suitable for our needs.

<u>Length and area of transect</u>**:** The transects are only as long as it takes to get the number of individuals decided upon, once the width has been chosen. However to sample all classes of plants along the same transect and make good comparisons between different classes, both length and width must be considered simultaneously (next section). The length of one transect to be used for several different classes should be established by the length to sample either the dominant or least dense class (i.e. canopy trees in most forests).

Although area is not a central consideration of the variable transect, it nevertheless can be very useful, and is worth estimating if there is time. If you quickly measure the distance it takes to get a certain number of plants, it allows you to make a rough estimate of the area and the density of the species. Measuring can be done quickly by pacing (walking in a uniform way, counting your steps, and by knowing the average length of your steps, estimating the distance); or, by running a thread from a small device that measures the length of thread that goes out. The latter can be done more easily if you have an extra person. Upon reaching the end of a transect or transect segment one measures the distance straight back to the starting point. For one person these transects are also a quick way to estimate densities of single species.

<u>To sample and compare different classes of plants with the same transect</u>: There is a complication in multiple sampling along a transect because different classes of plants occur at different densities, e.g. smaller plants are usually more dense than canopy trees. To have comparable samples of different classes, they should all ideally be sampled over the same transect length. Otherwise, the samples of the most dense plant classes would all be bunched up at one end of the transect and less likely to escape local clumping or to cover the full array of microhabitats. There are two ways to deal with this. One is to reduce the width of transects for classes of plants at greater densities (or increase it if less dense) so that the length will be the same to sample the same number of individuals as the least dense, e.g. canopy trees. The other way is to interrupt the transect and sample higher density plants at intervals (i.e. subsamples) to achieve the same goal.

The problem with the first solution is that it is difficult to know in advance what the density of individuals of another class will be, and therefore what width to use. As a rule, smaller classes of plants are more variable than canopy trees in density both from area to area and within a piece of forest. The problems with the second solution are the time it takes to establish segments or break-points in the transect such that plants can be sampled at intervals (i.e. to "stratify" the sample), and the longer time to estimate the area covered. As usual we need some hybrid compromise.

If one examines the forest to begin with to get a rough idea of how different the densities of other classes of plants are from the canopy trees, one can choose a width that is roughly appropriate, leaning toward wide rather than narrow. Erring by being slightly wider than necessary make it inevitable that the sample for plants with higher density will not overlap the entirety of the initial transect. But it is usually better that they be included within the initial transect length (usually of the dominant class --e.g. canopy trees) than extend beyond it.

After trial and error with different ways of marking and measuring subsample segments in the field for plant classes with greater density, we have concluded that it is usually too complicated and time consuming to make evenly sampled, evenly-separated segments along the length of the primary transect. If the width of the sample can be chosen well, the length will come close to covering the same distance as the primary transect. Otherwise, at the risk of a slightly biased sample, we suggest sampling half the number needed starting at one end of the transect, and the other half starting at the other end. This may leave an unsampled gap in the middle of the transect, which we will just live with. If the width chosen is too narrow (density underestimated), the two samples from opposite directions will run into each other, in which case we suggest continuing the sample of the second half by paralleling but not overlaping the first half until the requisite number of individuals has been reached.

As described above, classes of plants with clonal tendencies such as herbs or lianas should be sampled in small standard area units. Each species is registered only once per unit. The size of the unit is some compromise between the expected size of the clones, and a size small enough to get a measure of the relative abundance (or cover) of each species using the required number of "individuals" over the length of the established transect. For forest herbs we have usually used one or two meters as the distance of the unit on the 1-2m wide transect.

In this way the clones are seen as clumps of a species (as in the case of trees) and we are trying to sample in a way that will not over-emphasize the clump but at the same time not ignore its contribution to the relative cover by the species. We are thus measuring frequency of different species, and in such a way as to get a comparable measure of diversity for this class of plants at the same time. It could be argued that even the tree classes should be treated the same way -- with species only registered once per 50 m, for example. This would make the transects longer, not necessarily a bad thing for trees.

Geometry:

There is no need to run perfectly straight transects except to avoid getting lost and to minimize the possibility of biasing the data against certain micro-habitats (e.g. thick tangles) or of slightly overestimating the sample area where the transect bends. It is usually more important to stay within one habitat, such as following an elevation contour or following a curving ridgetop over different elevations, even if this requires a zig-zag transect. Along a stream, one can follow the meander curves to be sure that the transect stays on the bottomland. However, bending the transect to include specific species is definitely a bad idea.

The transect can be interrupted to jump over any discontinuities in the habitat that one is trying to sample, such as small streams, trails, or roads. In the extreme, the transect could be a series of fragments to sample only forest treefall gaps, for example. This is an advantage over poorly-chosen plots where unforeseen discontinuities can ruin the value of the plot as a sample of a single plant community (i.e. including two or more habitats in the same plot). Running a single transect across as many habitats as possible may be deliberate, as mentioned above, if time is very short, and might also be useful for measuring the width of the habitats where vegetation occurs in bands such as on meandering river floodplains.

Identification:

The more one learns about the flora of the area beforehand, the easier and faster it is to do the transects. It is helpful to have a reference collection, reference book, reference trail, or arboretum even if the plants do not have scientific names. It helps if one knows in advance which genera and families are likely to be confusing (e.g. Lauraceae, Sapotaceae, Nyctaginaceae) and not to be hasty placing them in species. Most taxonomic problems are at a larger geographic scale and the species at a local level are usually quite distinguishable (even if unnamable).

Given that usually less than 15 % (often less than 3%) of the species in an area make up 50% of the individuals, it is these common species that should be the focus of efforts at identification, since they are the ones that have the greatest impact on the rest of the habitat or local ecosystem. With enough sampling one can find out which species if any are truly or consistently rare, and some more attention paid to them. In the meantime, it is not much of a problem if many of the less-common species are left as "morphospecies" as long as they can be consistently recognized. The threat of extinction of rare species is mostly because of loss of rare habitat, and more attention should be paid to that.

The biggest identification problem even for common species is to see the correct leaves that go with the stem or to obtain a reliable voucher. This is the most frequent source of identification error. The branches of one plant are frequently intermingled with those of others. Identification can be almost impossible with moribund plants, especially those covered with climbing plants -- in which case they probably should be considered dead, and skipped over. That flaw in the data is a small price to pay considering the amount of data missed by wasting enormous amounts of time agonizing over identification of a plant that will soon be dead. The second most common identification error is in classifying juvenile forms as different species from adult forms of the same thing. This is difficult to overcome without experience and an existing set of collections of juvenile forms.

There are many ways to get voucher specimens if one is not able to identify the plant immediately, and there is no need to discuss those here. It will save time if one gets practice looking at the leaves on tall trees with binoculars and then finding fallen ones on the ground. Try to pick up several, because leaves can be quite variable in size and shape. Also make note of any notable characters such as smell, bark, latex, branching pattern, etc. One can make up common names along the way, noting the same name again if the species is encountered more than once -- without having to recollect it. Sometimes it is more efficient to mark all the difficult plants with bright flagging at first and check them more carefully on the way back.

Without nicely-prepared, full-sheet specimens of plant collections, professional taxonomists will be reluctant to work on them for identification. Taxonomists will be reluctant anyway because most of them are trained to look mainly at flowers and most of them have expertise in only one family of plants. If you will later be doing the identification yourself you will also have more difficulty if you do not make nice specimens of the leaves. Remember, the undersides of leaves are usually the most important for identification characters.

If you do not represent the local institution and are required by collection laws to leave 50% of your voucher specimens at the local institution, be sure to have enough duplicate material. Otherwise you may have to do such absurd things as cut leaves in half. Try to convince responsible officials that there is a difference between botanical herbarium specimens and transect voucher specimens. The problem is that a few of your vouchers may also be valuable as herbarium specimens. Most transects in the tropics do encounter new species or new distribution records. These and any good specimens with flowers or fruit should be made into regular herbarium specimens and given your personal collection number and information about date, locality, and size of the plant. Make sure the host institution gets the appropriate number of specimens and the information that goes with them. If there is only one good specimen, the host institution will usually let you borrow it immediately if you formally acknowledge that it belongs to them.

Unless you are drying the plants right away at your camp, you do not need a plant press. You need plastic bags and a marking pen for collections in the field. Put each separate collection in a different sheet of newspaper (even if it is just one leaf) and mark the paper with transect name, class, and plant number using permanent ink. Tie up a stack of specimens with string to form a large handful-size bundle, put it in a strong plastic bag, and pour enough 50% alcohol into the ends of the bundle to thoroughly moisten all the paper. This will prevent the specimens from rotting before they reach an institution where they can be dried properly. Once they are dried or sorted they can be sent or carried to the appropriate place for identification. The field work is fast, but the processing and identification of specimens is slower. Allow for this time in advance.

Analysis:

Keep it simple. Remember that the data is rough and the samples are never quite enough. Basic data for each class of plants in each transect should include: the number of species relative to the number of individuals sampled; a list of the species in order of abundance and the percentage of the sample that each species represents. In reports one can emphasize the most important species, such as those each making up more than 10% of the individuals, the top 10 most abundant, or those that make up 50% of all the individuals. Another useful datum can be the number of species that are represented by only one or two percent of the sample, or that are only represented by one or two individuals. This gives an idea of what proportion of the species are locally rare. If area of the sample has been calculated, it is important to include that.

Data from the different samples in the same habitat can be combined for some analyses. On the contrary, if the transect reveals an internal gradient or discontinuity, one can present the appropriate species data for each segment in a profile from one end of the transect to the other (using the x axis unless it is an altitudinal transect).

Having these data and making them available in publications or reports will permit others to make more sophisticated analyses and comparisons between transects and between classes, even if you do not. For most immediate conservation concerns such analyses are not needed, especially if based on a rapid preliminary inventory. But when it seems worthwhile, there are ordination techniques and several similarity and diversity indices (especially Fisher's alpha) available that can be applied to the data. One can also compare with plots and other sampling methods the amount of time invested and amount and quality of information gathered.

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