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DESIGNING FIELD STUDIES FOR BIODIVERSITY CONSERVATION

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THE NATURE CONSERVANCY

Chapters 1(part)& 2-3

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CHAPTER 1

Introduction: What's Science Got to Do with It?

Despite the potential of applied ecology, there is still disagreement about the extent to which ecological science is applicable to real-world problems.

—Alicia Castillo and Victor M. Toledo (2000)

This book is intended for all those who work toward sustainable and sustained conservation of the landscapes that surround them along with the native biota those landscapes support. What does *conservation* mean, though? It seems that each of us has a unique and constantly changing definition. At this moment my own definition of conservation is *the field of study and action that concerns the management of the landscape so as (1) in the short and medium term, to minimize or buffer negative effects of human beings on nature, which includes the landscape's human inhabitants ourselves, and (2) in the long term, to provide other living beings with the maximum number of alternatives for tolerating and surviving our species' brief presence on this planet.*[1]

Getting at Conservation

How might conservation be achieved? The effects—positive, negative, and neutral—of humans on landscapes are the cumulative result of the individual choices that persons and institutions make. Perhaps sustainable and sustained conservation can be achieved only through education at all levels of society so that today's children, tomorrow's adults, become familiar with their natural surroundings, recognize the consequences that alternative decisions might have on those surroundings, and make

Conserving the local landscape

↑

Designing and applying conservation guidelines

↑

Knowing the possible consequences of
alternative choices among guidelines

↑

Undertaking scientific inquiry (research)
in the local landscape

Figure 1.1.
Why scientific inquiry should play a role in conservation and management.

decisions thoughtfully (Feinsinger, Mangutti, and Oviedo 1997; and see chapter 10). While we strive for that distant goal, though, management by conservation professionals, in consultation with local communities, provides one practical approach to biodiversity conservation (figure 1.1).[2]

How should such management be carried out? The people responsible must develop practical guidelines and apply them to local landscapes in or out of protected areas (figure 1.1). But where do these conservation guidelines originate? Ideally, the people who will implement them will first consider the possible consequences of each reasonable choice and then select the alternative most likely to favor conservation goals while being acceptable to most local communities. By what means, though, can conservation professionals assess the likely consequences of each alternative? Can they simply follow their gut feelings? Sometimes—if and only if their insight into the landscape's natural

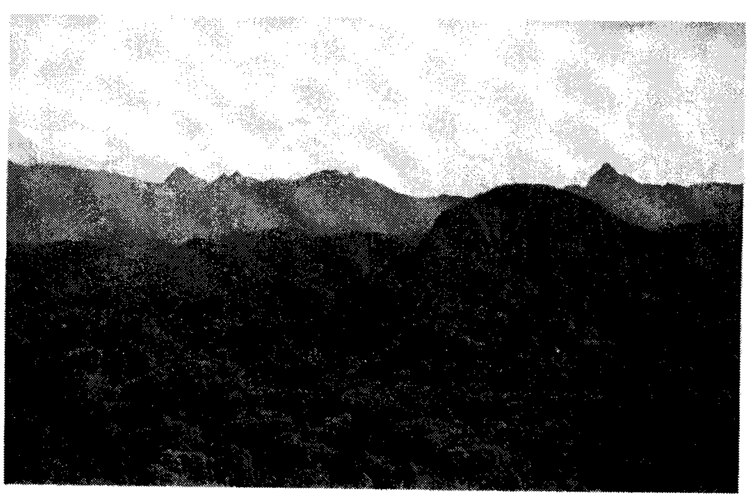

Figure 1.2.
A landscape managed for conservation (Reserva Natural La Planada, Nariño Department, Colombia).

Box 1.1. It Might Sound Good, but Will It Work for You?

In 1983, in the discussion section of a short paper in a widely read scientific journal, D. H. Janzen wrote the following sentence: "It is hard to avoid the conclusion that in some circumstances, it may be much better to surround a small patch of primary forest with species-poor vegetation of non-invasive species of low food value [e.g., grain fields, closely cropped pastures, cotton fields, sugar cane] than to surround it with an extensive area of secondary succession rich in plants and animals that will invade the pristine forest." Janzen clearly intended to provoke conservation biologists and managers into undertaking critical tests of this possibility in their own landscapes—note his words "in some circumstances." Instead of stimulating careful, site-specific evaluations, though, that sentence and a similar one in the article's summary have been lifted from context and cited uncritically by so many authors that they have achieved the status of a universal law for conservation professionals. The result has been an inordinate number of generalizations, and (rumor has it) even management policies all assuming that nearby second-growth habitats must be having a pernicious influence on conservation of protected areas throughout Latin America—without the idea being further tested.

Janzen's suggestion actually sounds eminently reasonable in terms of both common management objectives and natural history. Indeed, the suggestion may be the best strategy for conserving a given reserve's original vegetation under some circumstances. You'll see the paper cited at several other points in this book. Hold on, though! Before you too rush outside armed with machete, shovel, driptorch, and shotgun, eager to level all the nasty, species-rich second-growth vegetation and attendant animals within or nearby the area you manage and to replace these with innocuous soybeans, pasture grasses, or asphalt pavement, please reread the sentence and then read Janzen's entire paper. You'll find that the statement is a carefully couched speculation based on the author's incidental observation that plants of some second-growth species were colonizing one sunlit gap created by one fallen tree in one small remnant of one singular tropical dry forest in northwestern Costa Rica. Considering this, should you undertake a costly and drastic management plan for your reserve, which almost certainly differs in every conceivable way from Janzen's patch of Central American dry forest? In your particular landscape, might second-growth vegetation have positive as well as negative effects on the persistence of original vegetation and animals? Might the positive effects even far outweigh negative ones, if any? How might you find out, so as to come up with the best possible conservation guidelines?

In a similar vein, despite the appeal and biological reasonableness of the concept of "habitat corridors," some have questioned whether it is wise to rush to implement such corridors throughout temperate and tropical landscapes without having a better idea of their cost effectiveness, conservation effectiveness, and site appropriateness (e.g., Simberloff et al. 1992; Crome 1997; Schwartz 1999). It's likely that each case is unique. As Crome puts it, "Be suspicious of all but the most obvious generalities. Completely disbelieve the obvious ones."

history and social context is acute. Or should managers defer to "those who must know better" and base their guidelines on appealing, reasonable-sounding, and widely accepted ideas encountered in a published paper or heard at a conference? I certainly hope not (see box 1.1). Instead, might conservation professionals themselves evaluate the various alternatives in the very landscape where they would be applied (figure 1.2)? Yes, through thoughtfully designed and cautiously interpreted studies carried out firsthand (figure 1.1). How might such studies, on the ecological consequences of alternative management decisions, be designed well and interpreted cautiously? By using the approach of scientific inquiry.

Getting at Scientific Inquiry

Let's back up. What do *scientific inquiry* and *science* really mean? *Formal science* (or *basic science*) consists of two components that are linked by a dynamic process (figure 1.3). One component is the body of accumulated and continuously accumulating observations (data) that researchers generate with reference to the other component, the body of concepts that provide the current frame of reference. In turn, the body of concepts is constantly reevaluated and modified in light of the incoming data. The science process, or scientific inquiry as defined below, provides the means to cycle back and forth between concepts and data.

If science consists of a dynamic cycle, as in figure 1.3, is the isolated act of gathering data "science"? No. Does a long published list of observations (data) bereft of a conceptual context constitute science? No. Does sitting at one's desk and proposing a new theory make one a scientist? No. Does the use of sophisticated electronic instruments or complex statistical procedures justify applying the name "science" to any endeavor? No. Science requires that all four elements illustrated in figure 1.3 be present: the two boxes and the two arrows.

Combining the Two

In this book I'll stress *scientific inquiry,* the cycling process of figure 1.3, rather than dwelling overlong on details of the figure's two boxes. In the broad sense, scientific inquiry is ***a means of asking and answering firsthand, as objectively and precisely as possible, a question about a small piece of one's***

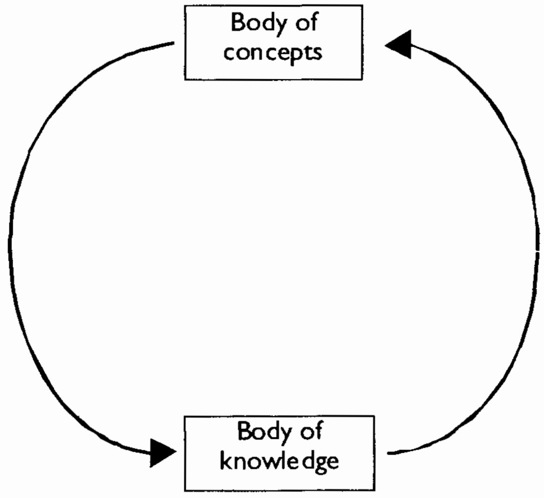

Figure 1.3.
Essential elements of formal science. Concepts and ever accumulating knowledge are related to one another through the process of scientific inquiry, as indicated by the arrows. The cycle may stand alone, as in "pure" or basic science, or may relate to applications such as technology or (in our case) conservation.

surroundings and then reflecting cautiously on the implications of the answer to the larger world. The quandary is that the concerns of conservation professionals and field ecologists often involve a fairly grand spatial scale on the one hand, and a fairly extensive time scale (the foreseeable future) on the other. In order to make the "correct" conservation decisions or the "correct" interpretations of ecological phenomena with absolute certainty, we'd have to be omniscient regarding that grand scale in time and space.

We aren't omniscient, though. We can't investigate simultaneously all possible individual organisms, populations, species, points in space, and landscapes of interest, nor can we evaluate the consequences of every possible variation of each feasible conservation guideline. We can only work in present time; we have only a fuzzy idea of those past events that might have caused present-day phenomena, and we certainly can't know for certain what the future portends. Thus, conservation scientists and others are restricted to working with "best guesses" based on the information available. That information comes from a *sample* restricted in space and time. We wish to *extrapolate* in as error-free a way as possible from that limited sample to the larger (and future) world where conservation guidelines will take effect or our conclusions might apply. Scientific inquiry guides us in (a) framing the question; (b) figuring out the most practical, meaningful, and objective way to obtain the sample so as to answer the question; (c) choosing the right tools to help get at the answer; (d) interpreting the results; and (e) extrapolating as cautiously as possible to the larger arena of conservation and management decisions.[3]

This book is meant to guide you, the reader, in the practical use of scientific inquiry as a tool for conservation in protected areas and in the "semi-natural matrix" (Brown, Curtin, and Braithwarte 2001), or for studies in basic field ecology, wildlife biology, and related fields. Along the way, the text will address a number of specific concepts, approaches, useful quantitative tools, and concerns or warnings. This will be done, I trust, in a commonsense rather than a technical manner. For example, frequently I'll raise concerns about approaches, techniques, and labels that are currently fashionable in biodiversity conservation, not in order to discredit them forever but so that you will think twice before rushing out to apply them uncritically to your particular landscape. I'll also point out that basic science has a great deal to offer the practical realm by helping to provide the conceptual frameworks that generate conservation concerns and important management questions (Poiani et al. 2000; The Nature Conservancy 2000). Likewise, teamwork between trained ecologists and managers (who may be one and the same person), plus other professionals such as sociologists, can streamline the sequence illustrated in figure 1.1. Nevertheless, as you'll see in chapters 2 and 10, the tool of scientific inquiry is by no means the exclusive province of professionals (Cooperrider 1996), nor does its effective use depend on an intimate familiarity with the two boxes of figure 1.3.

CHAPTER 2

The Inquiry Process

> If science is to help in biological conservation, it must be a much more inclusive and widespread sort of science than we know now.
>
> —Allen Y. Cooperrider (1996)

Any scientific inquiry whatsoever begins with a question about the features of one's surroundings. Depending on the interests of the investigator, the scale of those features might be that of subatomic particles, genes, whole organisms, species, entire landscapes, continents, our solar system, or the galaxies making up the universe. The questions that many ecologists and conservation professionals have, and the concerns that generate the questions, tend to involve the spatial scale of landscapes even if the focus is on a single species. In particular, conservation concerns might arise from a number of sources. Most have to do with how the protected area, its surroundings, or species of concern might be affected by different events, threats, or, of course, possible management guidelines—the last including alternative ways to counter a given threat (see figure 1.1). For example, your concern might involve the amount of firewood that can be extracted from the reserve without seriously compromising plant regeneration and soil quality, or the choice among alternative management guidelines that will lead to the most rapid recovery of a watershed from illicit gold mining activities. The key to enlightened conservation of protected areas or altered landscapes, just as to enlightened research in wildlife biology or forest ecology, is knowing how to frame questions. I urge you to go through the exercise of box 2.1 before reading any further.

Box 2.1. Practice with Observing the Landscape and Framing Questions

Grab a notebook and pencil. Go outdoors and find a miniature landscape. This could be a flower box, a patch of weeds bordering the street or trail, the visitors' parking lot at a protected area, moss-covered stones, an abandoned field, a school yard, a cow pasture, the ground beneath a forest canopy, or the trunk of a large tree. Select and mark off a small parcel, of about 50 × 50 cm, that displays a fair amount of "patchiness" (heterogeneity) within its borders. First, carefully examine the landscape you've just demarcated. Then spend about five or ten minutes sketching a crude map of the major "ecological elements" the landscape contains—for example, different types or forms or patches of plants, bare soil, leaf litter, insects and spiders, stones, fallen twigs, cracks in the cement, pieces of trash, patches of sun and shade, crevices in or lichens on a tree trunk. Then, spend ten minutes or so thinking up and writing down at least five *questions* (more if possible) that spring to your mind regarding what you've noted within the parcel's boundaries. No restrictions apply to the subject matter or format of the questions. Feel free to poke at things with your fingers or a stick. Most important, don't hesitate to write down any question that occurs to you. Rule Number 1 is, *there is no such thing as a stupid question.* Some questions might lead more easily than others to firsthand inquiry (the theme of chapter 3), but all questions are valid as such. Once you feel at ease posing questions about what you see, you've mastered the most critical phase of scientific inquiry.

The Formal Scientific Method: Too Academic?

Now that you're experienced at generating questions at the level of landscapes, albeit landscapes in miniature, let's discuss scientific inquiry as it might proceed from such questions. By any definition, scientific inquiry involves progressing through a series of logically related steps that eventually allow one to provisionally answer, or to revise, the original question as objectively as possible. Formal science and trained scientists, in theory at least, employ a detailed scheme called the *scientific method* or the *hypothetico-deductive method* (figure 2.1).[1]

In the formal scientific method, the question loses the punctuation and becomes a declarative statement, the *prediction*—but only after going through the three stages that make up the top line of figure 2.1. First, either on its own or stimulated by a firsthand observation about the scientist's immediate surroundings, a general concept (theory) or working frame of reference (paradigm) suggests to her that a particular relationship, pattern, or effect might occur in the universe at large, including but by no means restricted to those surroundings. This proposal is then formalized as the scientific hypothesis, or more accurately the scientific alternative hypothesis (scientific H_A). Naturally, the investigator recognizes that this possibility is only one of two, the other being that no such relationship, pattern, or effect really exists (the scientific null hypothesis H_0). Please note that scientific hypotheses are entirely distinct from the statistical null and alternative hypotheses that are discussed in chapter 5.

The scientist cannot, of course, evaluate the two scientific hypotheses or the theory that generated them under all possible conditions of space and time where they might apply. She has only the immediate surroundings, and the present time, for such a test. Therefore, the third and final step of

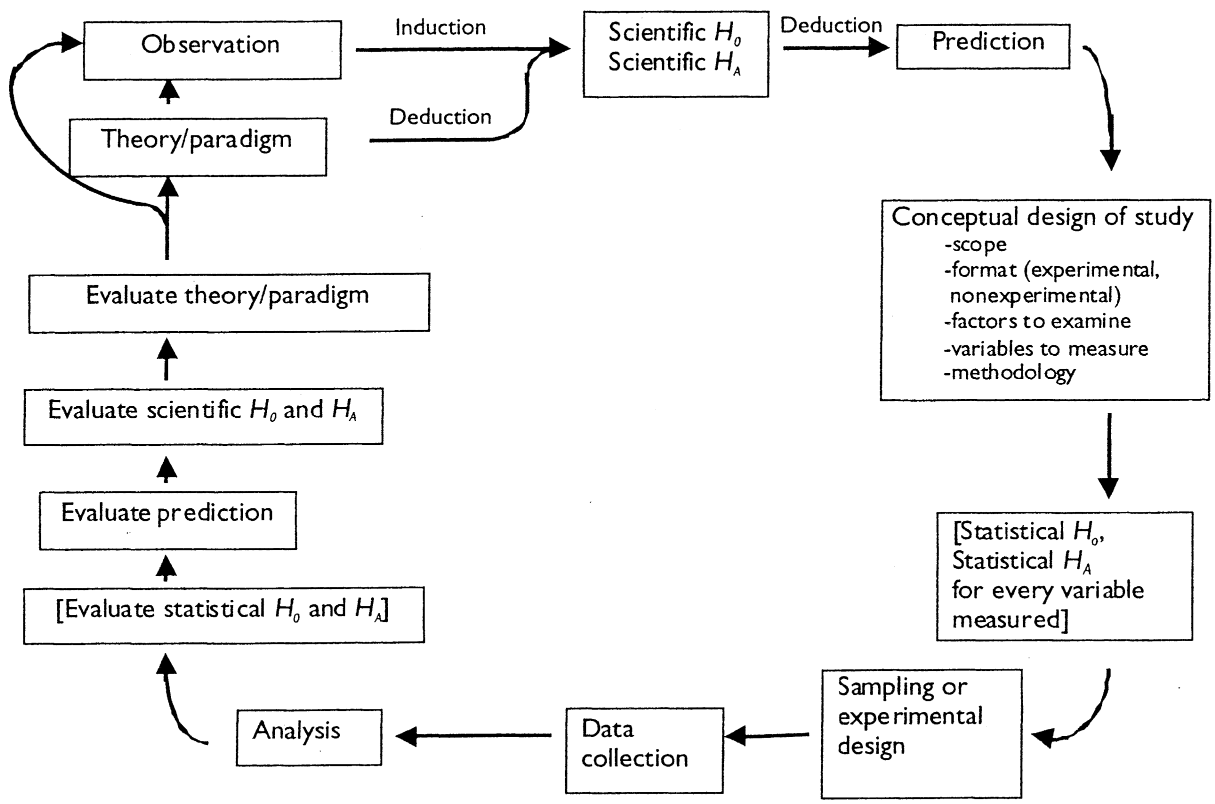

Figure 2.1.
The formal scientific method. Here, scientific inquiry begins with the two boxes at the upper left: the theory or paradigm and the observation.

the questioning phase is to derive (deduce) a prediction that narrows the scope of the scientific (alternative) hypothesis to those immediate surroundings accessible to an investigation. The prediction specifies, "If the scientific (alternative) hypothesis is always true under Conditions X, Y, and Z, and my immediate surroundings present Conditions X, Y, and Z, then such and such will occur here and now." Here's a rather obvious example of this logic:

- PARADIGM: Vegetation interacts with the water cycle. Or,
- THEORY: Vegetation cover affects the rate of evaporation from the soil surface.
- OBSERVATION: I work in a forested reserve, and selected parcels will be clear-cut as part of the management plan.
- SCIENTIFIC ALTERNATIVE HYPOTHESIS: Clear-cutting changes the rate of evaporation from the soil surface.
- SCIENTIFIC NULL HYPOTHESIS: Clear-cutting does not change the rate of evaporation from the soil surface.
- PREDICTION: *If* clear-cutting changes the rate of evaporation from the soil surface anywhere and anytime, ***and if*** selected parcels are clear-cut in the forest reserve where I work, ***and if*** I measure

evaporation rates from the soil surface before and after clear-cutting, *then* I will record a change in those rates.

After specifying the prediction, the investigator moves down the right-hand side of figure 2.1 and then across the bottom toward the left, proceeding cautiously through the steps of study design, data collection, and data analysis. The results of the data analysis then allow her to clamber back up the left-hand side of figure 2.1, first evaluating the statistical hypotheses—if using statistical inference (chapter 5)—and then scrutinizing each of the first three steps, those on the top line, in reverse order. That is, if the data she's collected and the statistical analysis of those uphold the prediction, this result provides one more bit of support for the all-inclusive scientific (alternative) hypothesis, which in turn provides one more bit of support for the more general concept (theory) or the even more general frame of reference (paradigm). On the other hand, in formal science a convincing failure to support the prediction *in even a single instance* means that the scientist cannot reject the scientific null hypothesis; that in consequence the scientific alternative hypothesis is not supported in this instance and therefore cannot be universally true; and that the body of theory itself, even the paradigm, must be reevaluated and modified, leading in turn to new passes through the cycle of figure 2.1.

Scrupulously followed, the formal scientific method is an extraordinarily powerful means for advancing basic science in the manner of figure 1.3. Is the formal scientific method always the best framework for scientific inquiry, as defined previously? Perhaps not.

First of all, the formal scientific method is inappropriate to the goals of conservation initiatives, such as protected area management, or to goals of most field research in ecology and related fields (Crome 1997; Johnson 1999). The formal scientific method emphasizes scientific investigation as a direct means of evaluating the upper left-hand corner of figure 2.1 or the top box of figure 1.3—the body of concepts (theory)—rather than focusing on the particular prediction or specific question that has to do with one's surroundings. That is, if she faithfully follows the formal framework of figure 2.1, the scientific investigator exploits predictions and their tests (research projects) simply as mechanisms for evaluating the much grander "yin and yang" of the two universal scientific hypotheses. In this manner she then gains fame (though rarely fortune) either by providing one more bit of support for the universal truth of the scientific (alternative) hypothesis and the general concepts currently in vogue, or else by soundly thrashing the alternative scientific hypothesis and forcing a severe modification of the theory. In this scenario, the forest tract whose parcels are clear-cut is of little interest in itself. Rather, it's a single "trial" for evaluating the universal scientific (alternative) hypothesis that vegetation cover affects the rate of evaporation from the soil surface anywhere and everywhere.

If you're the conservation researcher or protected area manager, are you more interested in the universal validity of the scientific hypothesis regarding vegetation cover and evaporation rate, or in the particular consequences of logging within the particular reserve where you work? If you're a field ecologist examining the relationship between food scarcity and interspecific competition in hummingbirds, are you more interested in the universal validity of the statement that food scarcity and interspecific competition are related for any organism in any context, or in what's happening with the hummingbirds within the particular habitat where you work? Let's consider another conservation professional working in a Latin American protected area. This person is worried not about the set of all protected areas worldwide, but about the one for which he is responsible. It doesn't matter to management of this particular protected area whether the most effective means of restoring a watershed degraded by gold mining here is also the most effective means in Siberia, Zimbabwe, Australia, or even on the other side of the mountain range. The urgent question he is asking concerns the immediate surroundings only, where the answer in turn will guide policies pertaining specifically to those surroundings (see figure 1.1). The first two steps illustrated in figure 2.1—the general concepts along with the observation, if any, that catalyzes the process and the universal scientific hypotheses—should simply serve as a convenient means of getting to, and framing, that urgent question whose scope is restricted in time and space. And rarely, if ever, will the conservation professional benefit by turning a clearly presented, open-ended question (see chapter 3) into a rigid, formalized, declarative prediction.

The Inquiry Cycle: Too Simple?

Second, let's face it, the formal scientific method as it is usually presented (for example, in figure 2.1) intimidates most people, including many trained in Real Science. Even if its complex terminology and apparent philosophical rigidity don't frighten people off, how many have simply memorized (or used blindly) the scientific method without any real understanding? Please squint suspiciously at figure 2.1. All those jargon-filled boxes, the fundamental concepts of the formal scientific method, can be collapsed into four basic, logical steps: the "inquiry cycle" (figure 2.2). Let's rephrase the preceding section in commonsense language and focus it on answering our specific questions rather than on evaluating universal concepts.

As always, inquiry begins with an observation about one's surroundings. The observation never stands alone, though. Consciously or unconsciously, the observer always places it in the context of a broader concept or concern. That context need not be formal at all. For example, you observe a two-legged being of about your size holding a slender, long object made of wood and steel, approaching several large feathered things sitting in a tree. Based on previous experience, you place these observations in a broader context: a hunter from the local community is about to shoot a chachalaca (charata), a large edible bird. The observations placed in context stimulate you to *construct the question*—just what you did in the exercise of box 2.1. In this case, the question that leaps to your mind might be, "How does the abundance of chachalacas in the forest change with respect to distance from communities?"[2] In essence, the entire top line of figure 2.1 collapses into the first step of figure 2.2: coming up with the question.

Next, as the investigator you take *action* to answer the question, by designing and carrying out a study at the scale to which the question refers. This step, which covers the right-hand side and bottom line of the cycle in figure 2.1, results in a set of findings or data.

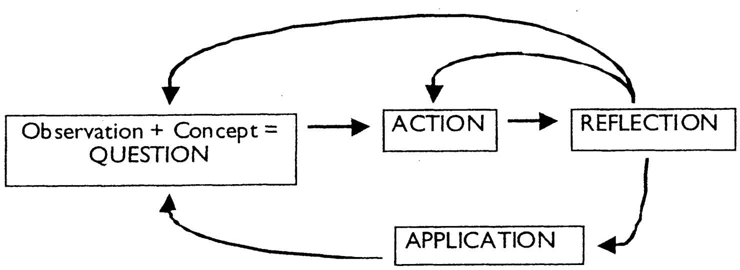

Figure 2.2.
A different scientific method: the simple "inquiry cycle."

Once the action step has provided a specific answer—the observed results—to your particular question, the crucial third step of *reflection* takes place. In essence, this step covers the entire left-hand side of figure 2.1 and more. Reflection takes several forms, as the leftward pointing arrows in figure 2.2 indicate. What do your findings imply, with respect to the original question? Has your initial reasoning been supported, or not? Could other phenomena, not originally considered in the question, have produced the same results? Should the question have been oriented differently? What are the conclusions you're willing to draw? Just how far, with respect to other locations, times, or conditions, can you justify extending your conclusions and speculations? How confident do you feel about basing real-life decisions on those conclusions and speculations? Did events during the action step, or the results themselves, bring up new, intriguing, or urgent questions, each capable of initiating its own cycle of inquiry? Finally, you should closely reexamine the action step itself, especially the way you designed it and carried it out. Was the study fully adequate to answer the original question? Might the results have been influenced by biases in the methodology or sampling? Might unforeseen complications of natural history, behaviors of animals, features of plants, subtle ecological interactions, or weather events have influenced the particular results such that the question as originally posed hasn't yet been answered directly?

The reflection step is as crucial to questions in biodiversity conservation as it is to those in any branch of basic science. Far too few inquiries, whether carried out by laboratory scientists or conservation professionals, include adequate reflection. Results are summarized and "written in stone," conclusions are drawn, without considering further their validity and significance with regard to the original question. Why is this a problem? Because, in the particular case of protected area management or other conservation endeavors, the inquiry cycle includes a fourth step: *application*. The results and interpretation of a study strictly circumscribed in time and space will guide practical decisions affecting larger scales and future times. These decisions may have far-reaching effects on the destiny of the landscape in question. Therefore, the reflection over "how far can I extend my speculations and conclusions" takes on tremendous importance. Furthermore, the reflection process must continue once the application takes effect, once conservation guidelines that are based on careful scientific inquiry are implemented. That is, the effect (and effectiveness) of those guidelines should constantly be monitored and reevaluated. Some effects may be unexpected, giving rise to further concerns and questions that in turn catalyze new cycles of the entire four-step process illustrated in figure 2.2.[3]

Is the "inquiry cycle" diagrammed in figure 2.2 sufficient for accomplishing basic science (figure 1.3)? You'd certainly find disagreement on the answer to that question among philosophers of science: many would find figure 2.2 too simplistic. As a professional researcher, though, consciously or unconsciously I've based my own investigations on it; as a teacher, I've exploited the inquiry cycle with various groups ranging from elementary school teachers to postgraduate students in ecology and conservation professionals. If you're dealing with questions not in conservation and management but in field ecology or other basic studies, you simply need to change the word "application" in the fourth step to "wider universe" (Feinsinger, Margutti, and Oviedo 1997). That is, just how far can you generalize from your results to phenomena that might happen, or have happened, in other places or at other times? Later in the book I'll often refer back to this four-step approach, for example, when discussing means for bringing local communities into the inquiry process (chapter 10). Most people use some form of the inquiry cycle, often labeled "common sense," in their daily lives. Nevertheless, you're probably a bit skeptical, muttering to yourself, "Well, yes, the scheme in figure 2.1 is no use to me because it's too academic, but isn't the one in figure 2.2 also useless because it's oversimplified?" Before we address those doubts, let's consider one case of this four-step scientific process (figure 2.2) as practiced in the field.

Do Campesinos Practice Scientific Inquiry?

A farmer (campesino) living in the wet highlands of northwestern Ecuador, or nearly any other landscape with small-scale agriculture, must make "management decisions" almost daily. For example, he must decide which cash crop to plant in a one-hectare parcel of recently cleared land on a certain hillside (figure 2.3). Because of the time and energy required to plant and cultivate the parcel, he wants to ensure beforehand that the crop he chooses will yield under the problematical conditions of nearly constant cloud cover, cool temperatures, and high humidity that characterize the parcel. Having other parcels to tend, he is in no particular hurry and would rather wait a year than rush into making a wrong decision regarding the new clearing. He decides to make a limited trial of two crops: a tuber crop, melloco (*Ullucus tuberosus*), and a legume crop, chocho (*Lupinus mutabilis*). So, after preparing the plot, he plants a few melloco tubers or chocho seeds in each of several spots scattered throughout the parcel—well aware that there's variation in soil and moisture conditions over the parcel itself, and that he wouldn't learn anything useful by confining the trial to one corner only or by planting the chocho in one corner and the melloco in another (see chapter 4). During the growing season he occasionally visits the site and checks on the growth and health of each crop. At harvest time, he discovers that a fungus has attacked most of the chocho plants and pod production is near zero, whereas the melloco plants seem healthy and have produced reasonable numbers of tubers.

Clearly, then, *under the conditions of his trial*, the melloco makes the better choice. Before running out to purchase enough melloco tubers to plant the entire hectare, though, the campesino ponders a bit. Have weather conditions of the past year been typical, or was the year unusually wet, perhaps favoring the growth of the fungus and causing an atypical failure of the chocho crop? Is it reasonable to expect next year's conditions to resemble those of the past year, or not? Also, he has a different one-hectare parcel at a lower elevation, with exposure, moisture conditions, and slope quite different from the parcel he has just evaluated. Do the results from the first trial permit him

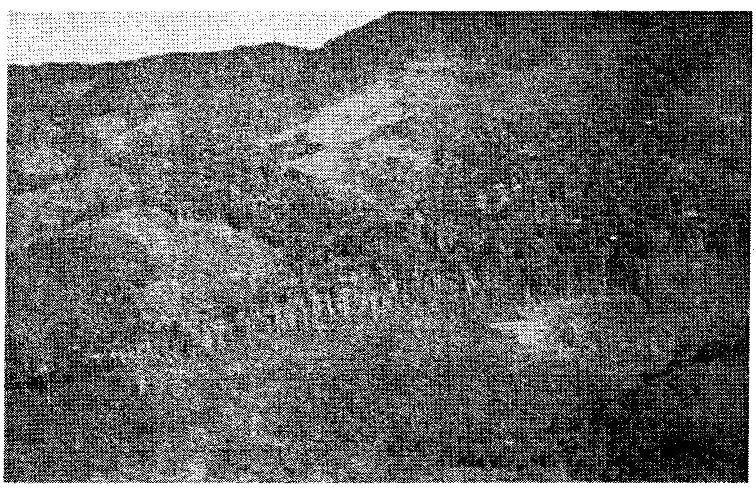

Figure 2.3.
An agricultural mosaic in the Cordillera de Toisán in highland Ecuador (Imbabura Province). Some parcels are used for subsistence crops or livestock pasture, others for cash crops.

to assume that melloco will be the superior crop for this rather different parcel as well? After some thought, the campesino decides to take the risk and plant melloco in the first 1-ha parcel where he carried out the trials, despite uncertainty about next year's weather. He also decides, though, not to risk planting melloco in the second, quite different parcel until he has had the chance to undertake analogous trials there, perhaps involving other potential crop species.

Compare the sequence of steps (observation and doubt, trial, reflection, and decision) through which the campesino progressed, from the starting point of wondering which crop might do better through the end point of planting the selected crop, with the inquiry cycle illustrated in figure 2.2. Has he practiced scientific inquiry? Yes, absolutely. Has he undergone formal training in science? Almost certainly not. He has three neighbors, who base their own decisions about which crops to plant where on, respectively: (1) the advice of the newly arrived agricultural extensionist, (2) the opinions of a great-uncle whose farm is in another watershed, and (3) the advice of an almanac. Are the neighbors also engaging in scientific inquiry, or not?

The "Management Cycle" and the "Field Research Cycle"

Now, let's develop two compromise frameworks for scientific inquiry, somewhere between the academic formality of figure 2.1 and the simplicity of figure 2.2. First, what if you're a conservation professional? You need a scheme for arriving at the "best guess" regarding alternative possibilities for guidelines. Figure 2.4 presents one such scheme.

Here, the inquiry process begins with a particular concern. This might arise from any one of a number of sources. For example, you might work in a protected area and observe directly a current or potential threat to the reserve's integrity, a "stress" in other words (The Nature Conservancy 2000). Or your concern might arise from prior knowledge (your own or someone else's) of what *might* be a problem. For example, maybe you've just read the article by Janzen (1983)—see box 1.1—and now wonder if the abandoned pastures, laden with weedy pioneer shrubs, that border on the reserve's primary forest might be overwhelming the forest's soil seed bank and altering its internal vegetation dynamics, in comparison with the well-maintained, weed-free cattle pastures or cornfields bordering other parts of the reserve. Or your concern might simply arise from commonsense reasoning. For example, given that selective logging occurs in the reserve's perimeter and that a choice exists between oxen and mechanical skidders for extracting the logs, it makes sense to wonder if one or the other choice will wreak less damage. Or the concern may arise from local community members (chapter 10). Perhaps they wonder just how much exploitation a critical population of medicinal plants can tolerate without dying out. Finally, the concern might originate far from the protected area itself: for example, the central ministry has just sent you a directive to evaluate a certain management policy or a certain type of perceived threat.

The management concern generates that all important step: framing a question that will be answerable through firsthand inquiry (figure 2.4). In chapter 3 we'll discuss the ins and outs of framing questions. A well-framed question leads readily to the conceptual design of the inquiry proper, which chapter 4 will explore at length: which data to record, where, when, how, and by whom? What's the scope of your question? How can the inquiry be designed so that you can cautiously apply its results over that entire scope? Does the question require an experiment or not? What are the factors or relationships you'll evaluate? What particular sorts of data will you collect? What methods will you use to collect them? Finally, will inferential statistics be useful? If so, before proceeding

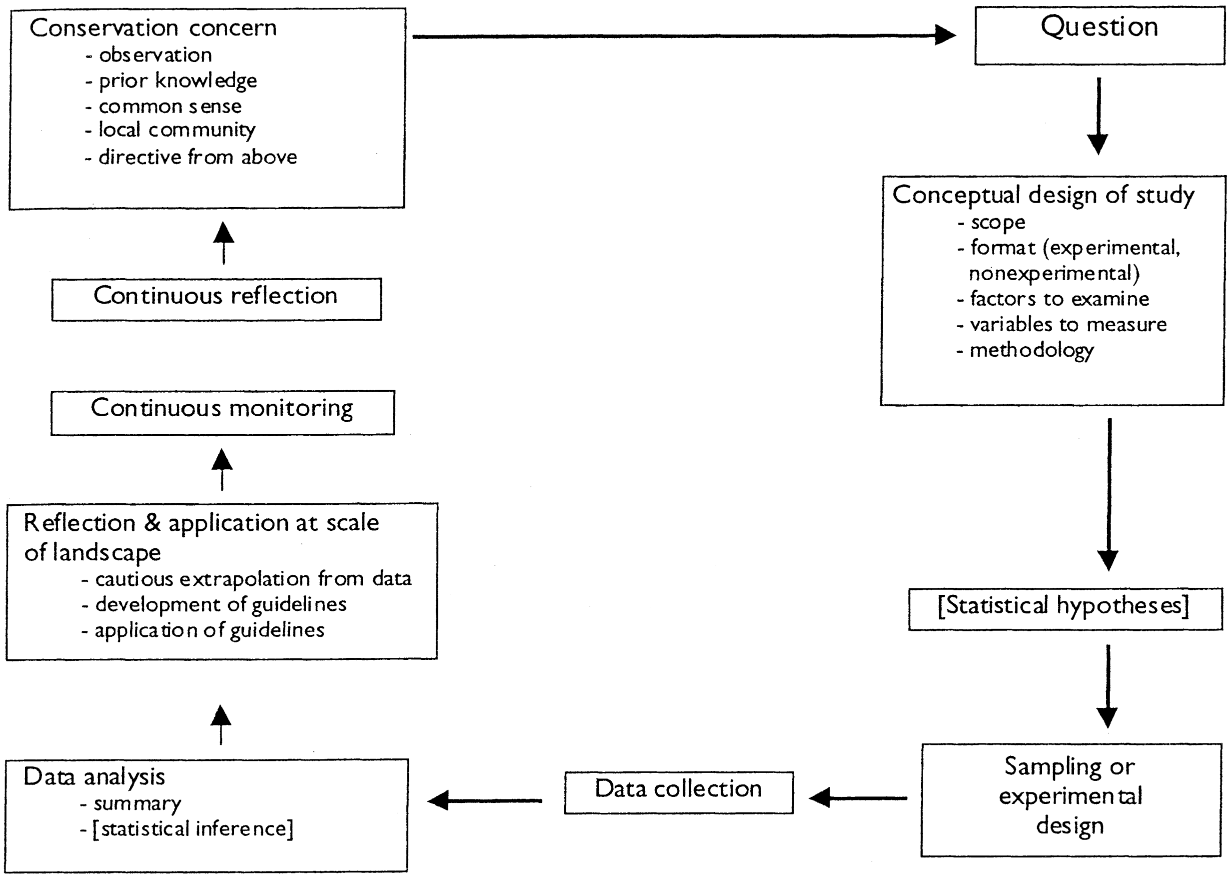

Figure 2.4.
The "management cycle": The inquiry cycle of figure 2.2 expanded for scientific inquiry applied specifically to conservation concerns and other questions that will lead to guidelines or management decisions. The process begins at the upper left.

further you must set up formal statistical hypotheses for each sort of data you'll collect, as we'll discuss in chapter 5. Whether or not you'll use inferential statistics, how many samples should you take or experimental trials should you run? Chapter 5 and appendix B address this crucial and sometimes overlooked decision.

At last you collect the data. After analyzing, summarizing, and (if required) applying statistical inference to the data (figure 2.4), you must sit back and reflect, just as in the third step of figure 2.2. What do the results really mean? Again, given that the data represent the here and now, whereas conservation decisions will affect the there and later, just how far can you apply the conclusions you've drawn? Chapter 6 will consider this crucial question from the viewpoint of natural history. Finally, following reflection, you and others concerned use your inquiry as one piece of information for proposing conservation guidelines and putting them into practice. That's not all, though. As before, you must continue to assess effects of the guidelines by means of a rigorous monitoring program. Eternal monitoring is the price of conservation. Eternal vigilance is the price of monitoring, though, and rather than simply accumulating great gobs of monitoring data, you must continually evaluate and reflect upon those data as they accumulate. Again, unforeseen side effects of the chosen guidelines may generate new concerns, which in turn should initiate new cycles of inquiry.[4] Please note again the critical difference between the "management cycle" (figure 2.4) and the formal scientific method (figure 2.1). Here, your inquiry revolves around your own landscape and the events therein. You're not out to support or refute the effectiveness of particular guidelines the world over.

Likewise, if you're a student or professional in field ecology, wildlife biology, or a related field, would you be perfectly comfortable in considering your lengthy and difficult research project as just one tiny bit of information used to evaluate a universal scientific hypothesis without any other intrinsic value? If your final results fail to support the prediction that interspecific competition among hummingbirds and food abundance are related at your site, are you prepared to trumpet to the world, "The scientific (alternative) hypothesis, of a universal relation between interspecific competition and abundance of resources, was not supported. Therefore, we must abandon that hypothesis forever and reevaluate the theory and paradigm of interspecific competition"? I doubt that you'll answer yes to either question. Sorry, but if you're an ecologist or other field biologist, you're not doing Real Science in the formal sense of figure 2.1. Instead, you recognize the complexity of field ecology and natural history and recognize that every situation is likely to be unique because of the myriad other factors influencing what goes on here and now (Crome 1997). You're most interested in a particular question regarding these hummingbirds in this landscape and at this time, although in the discussion section of your thesis or paper you'll be happy to speculate on how your results might apply to events elsewhere.

Actually, though, you *are* engaging in Real Scientific inquiry—not that of figure 2.1 but rather that of figure 2.5. You're following the "field research cycle." Observing hummingbirds sparring with one another over a flower patch and knowing that the number of flowers is likely to vary over the year, you've thought about the concept of interspecific competition, and an idea for a scientific study begins to form. That general idea—and please don't confuse the issue by labeling it "hypothesis"—leads to a specific question (see chapter 3). You'll answer the question by designing the particulars of the study, collecting data, and reflecting on all aspects of the results—including whether they fit with general theory and with results of other studies on the theme. The major difference between the cycle you follow as a field ecologist (figure 2.5) and that which you follow as a conservation professional (figure 2.4) is that this time you're not going to apply your results to management decisions on hummingbirds or flowers, or to monitoring the consequences of such decisions.

Any of the four methods presented has potential for guiding scientific inquiry. Take your pick. Perhaps the goals of figure 2.5 are most appropriate to your interests. Perhaps the applied goals of figure 2.2 or figure 2.4 are most relevant to your conservation concerns. Perhaps you're a physicist and figure 2.1 suits you just fine. Whichever the scheme used, though, the step of framing the question is critical, simply because some ways of framing questions lead to much more useful reflections and applications than others do. In the next chapter we'll focus exclusively on that step.

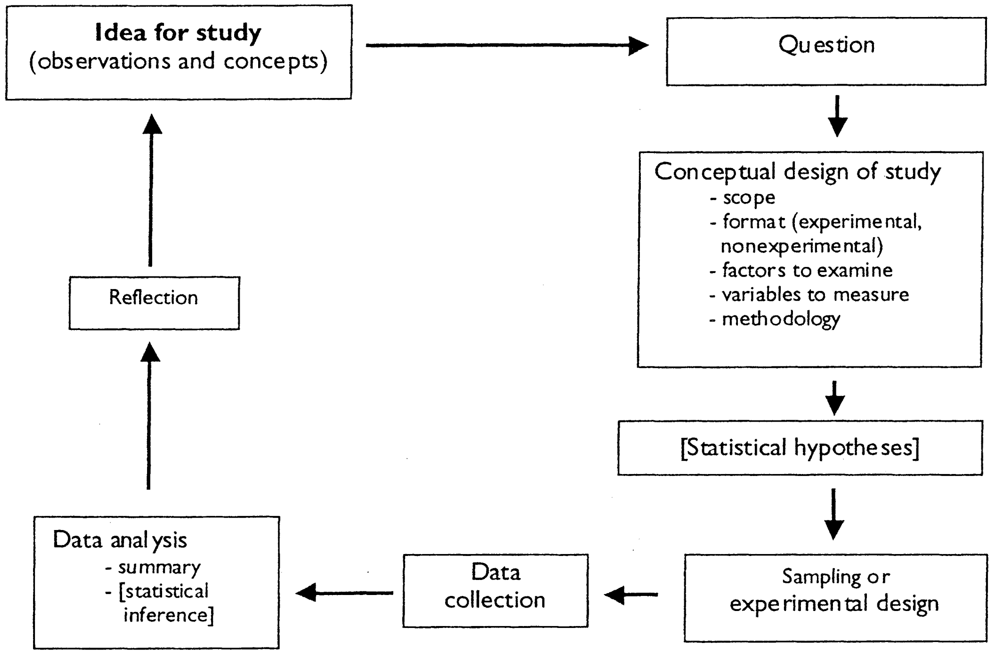

Figure 2.5.
The "field research cycle": The inquiry cycle of figure 2.2 expanded, or scientific inquiry applied to questions in basic field ecology and related approaches.

CHAPTER 3

So, What's the Question?

Asking the right questions is as important as answering them.

—Allen Y. Cooperrider (1996)

As figure 2.4 points out, conservation concerns or other sources (for example, the exercise in box 2.1) may spark numerous questions. Again, in one sense all these questions are valid. In another sense, though, some may be more valid than others. That is, in real life some questions are asked with the intent that they will generate clear answers that in turn will lead to effective conservation guidelines or solid scientific conclusions.

Please understand that this chapter and the book as a whole remain quite silent on the issue of which questions are the most important ones for conservation researchers—or others—to ask. You aren't reading a guide to conservation policy or to the hot topics in field ecology. It would be a serious mistake to pretend to instruct conservation professionals and field biologists on which issues or strategies they should investigate. Likewise, the examples listed later in this chapter are meant only to illustrate some questions that comply with the four criteria discussed below, not to serve as exemplars of the most burning issues to address. Now let's discuss those criteria: how might you frame your question so that it leads most readily to the complete inquiry cycle (figure 2.2), management cycle (figure 2.4), or field research cycle (figure 2.5)?

Framing Answerable Questions

A question should be phrased so that it's directly answerable by collecting data within a reasonable time frame. Questions such as "which?" "how many?" "where?" "when?" "what's the relation between?" "what are the immediate consequences?" and "what are the differences?" can often be answered directly through careful application of the scheme in figure 2.2, 2.4, or 2.5. They direct you to investigate patterns or events in the present day.

How many times during the exercise in box 2.1, though, did you frame a question around the word *why?* In contrast to others, "why" questions are at the heart of the reflection step (figure 2.2) but inappropriate for construction. You'll see this if you try to initiate a scientific inquiry with a why question. You'll be stuck. A why question directs you to detail the unknown events in the past that led to what you observe today. Unless you own a time machine, you can't do that. The why questions pop up when you're reflecting on your results, though. You don't answer them directly; rather, you propose possible explanations for your observations, you speculate, you consider alternative possibilities. Most important, why questions prod you to transform them into new, answerable questions that initiate new cycles of inquiry.

For example, the question "*Are* more seedlings of weedy pioneer plant species invading the reserve where it is bordered by second-growth vegetation than where it is bordered by cattle pasture?" is answerable through direct investigation, today. The question "*Why* are there more seedlings of weedy plant species in the first situation than in the second?" is what springs up if you've answered yes to the first question. The why question, though, can't be answered directly today, because it involves events in the past that may have influenced the arrival, survival, and germination of the seeds that produced the seedlings you see today. One possibility is that proposed by Janzen (1983), as described in box 1.1. That is, it's possible that in the recent past the second growth and the fruiting plants it contains had attracted fruit-eating birds and mammals, which, when returning to the reserve, defecated large numbers of those plants' seeds. As a natural historian, though, you realize that any number of other past events could also account for a present-day difference in seedling densities between different sites. These possibilities include differences in land-use histories, in rates of pathogen or fungal attack on seeds that lie buried in the soil, in seed predation by ants and rodents, in the rate at which seedlings themselves were attacked before you happened along, in exposure to wind, in other microclimatic features, and in the soil properties themselves—as well as pure chance. To answer the why question directly, you'd need to take the impossible step of examining all of these possibilities and many more besides.

Nevertheless, *reflecting* on why you might have obtained those particular results might lead you to consider seriously one of the possible explanations, frame an answerable question about what's happening right now with seeds or seedlings, and answer that new question with a firsthand inquiry. For example, let's say that you've observed that most of the invasive plant species do indeed have fleshy fruits and animal-dispersed seeds. Reflecting on this, you might propose that Janzen's (1983) scenario is indeed the most likely explanation for the pattern you observed previously, and the most urgent to evaluate before deciding on a management plan. Thus, the why question that surfaced by reflection during your first inquiry cycle (concerning patterns among seedlings) has now generated a second cycle. The second cycle might begin, for example, with the question "Do animal feces containing seeds of the invasive species arrive more frequently in forest bordered by second-growth vegetation than in forest bordered by cattle pasture?"

Avoid the temptation to begin a scientific inquiry with a question that really belongs in the reflection phase. For example, the questions "How might we manage the reserve so as best to maintain its biodiversity over the next century?" and "How can we design the education center so that it best encourages visitors to conserve their own surroundings upon returning home?" are urgent, compelling questions. They're questions for reflection, though, best answered by sitting around a big table and reaching a group consensus.

Framing Comparative Questions

A question should be a comparative one. The comparison should be that implied by the management concern (figure 2.4, upper left) or by whatever other concept generated the question (figure 2.5). A comparative question requires that you focus on that concern or general concept and allows you to address it during the reflection afterwards. By contrast, a noncomparative question is often a dead end, providing no basis for reflection or for proceeding further.

Let's imagine that your concern involves habitat corridors (see Beier and Noss 1998). The question "How many individuals and species of mammalian carnivores use this habitat corridor?" complies with the first criterion presented above: it can be answered by collecting data firsthand. Nevertheless, those data lead absolutely nowhere in terms of developing conservation guidelines. In contrast, the questions "Do more individuals and species of mammalian carnivores use a corridor of second-growth vegetation or one of primary forest?" "Do more mammalian carnivores cross an agricultural landscape if it has a habitat corridor than if not?" and "Is the corridor used more frequently at some seasons than at others?" all involve comparisons between two or more sets of conditions. Reflecting on the answers to these questions might lead to broad-scope guidelines regarding habitat corridors.

Of course, data gathered objectively in response even to a noncomparative question are valuable in their own right. Occasionally, it's impossible to muster the time and resources to examine the two or more sites, times, sets of conditions, or experimental treatments required by a comparative question. Nevertheless, by amplifying just a little bit the scope of a question that was initially noncomparative, the conservation professional can often greatly enhance the usefulness of results.

Consider a second example, a recently designated protected area that presently consists of a number of fragments of primary forest scattered in a sea of second-growth scrub. The overriding conservation concern is to maintain a high diversity of forest primate species. The reserve's conservation scientist looks at one particular forest fragment and asks, "How many primate species live in this forest patch, and of those, which are rare and endangered?" The question is valid, but will the results be of any use other than for describing the status of the particular fragment? If she changes the question to "Is there a difference in the number of rare and endangered primate species living in this fragment and in that other fragment of about the same size?" the investigator now has a comparative question, but it doesn't go much further than the first one. The comparison doesn't address the concern whatsoever. It involves no broad context, no general factor, no basis for making management decisions about the numerous other forest fragments scattered throughout the new reserve. Really, the second question is simply the first, noncomparative question squared.

If the investigator instead asks, "Is there a difference in the number of rare and endangered primate species living in this *small* fragment and that *large* fragment?" she's bringing in a much broader context (the concept that patches of different sizes may support different numbers, and identities, of resident species). She's also bringing in a possible key to management decisions: if indeed she finds a difference, then habitat fragments might be manipulated in particular ways to produce particular primate assemblages.

Of course, upon reflection, the investigator in this case realizes that examining only two forest fragments is not sufficient to generate guidelines. An observed difference in the two primate assemblages might have arisen from unique features of the two patches, features that have nothing to do with their distinct sizes (see chapter 4). Therefore, before proposing and applying management guidelines, she decides to survey a much greater number of habitat fragments that differ primarily with respect to the factor of size. So, her comparative question has now become "Do forest fragments of different sizes support different numbers of rare and endangered primate species?"

You may be chuckling over the naïveté of the investigator, saying to yourself, "What a stupid question! Everyone knows that larger forest patches have more species!" Please note that this real-life question is far from being stupid, though, and remember Crome's (1997) quote from box 1.1: "Be suspicious of all but the most obvious generalities. Completely disbelieve the obvious ones." In her particular landscape, the conservation scientist can't automatically assume that large forest patches will hold more endangered primate species than small patches just because several quite convincing theoretical papers tell her that such should be the case or just because results of some field studies undertaken in other landscapes happen to support that "conventional wisdom." It's quite possible that in her particular case the regenerating, resource-rich, second-growth scrub, or the border between forest and scrub, supports such a large number of primate species that small or intermediate-size fragments embedded in that matrix actually support the richest faunas, whereas large tracts of rather homogeneous forest support primate assemblages that are less diverse. The investigator won't know, and can't mount management guidelines, until she has dealt with the question firsthand by designing a study within her own landscape. Note that the criterion of "comparativeness" is just as critical to questions in basic field ecology as to conservation questions.

Framing Alluring Questions

The question should be an alluring one. That is, it should involve neither an answer that's already obvious nor an action step (figure 2.2) so tedious or time consuming that the data will be irrelevant by the time they're finally compiled. For example, the question "Which supports more native frog species, 700 hectares of marsh and swamp, or the 700-hectare paved parking lot for visitors?" is both answerable and comparative, thus complying with the criteria above. It doesn't merit a firsthand inquiry, though, as the comparison is nonsensical.

On the other hand, a question could comply well with all the foregoing criteria yet fail the test of allure, simply by requiring an inordinately long time frame or an inordinately complex plan for data collection. For example, consider the question "Which management tactic will result in the greatest diversity of canopy trees in next generation's forest, hand-planting seedlings of a selected diversity of primary forest species or allowing natural regeneration to take place?" The question could have extraordinary import to the long-term conservation of protected areas. In theory a definitive answer would settle the choice between two very different management approaches. Nevertheless, obtaining that answer through a well-designed firsthand inquiry might require several centuries and be of little use to conservation decisions that are needed *now*.

Framing Simple Questions

The question should be as free as possible of jargon and of technologies that require considerable expenditure and training. If it's not possible to phrase a conservation concern and the question that results in clear, understandable language, perhaps the question isn't so urgent after all. By using clear language and common names of plants and animals instead of Latin names, you may greatly increase your ability to involve local people in the full process of inquiry and conservation (see Cooperrider

1996; Margoluis and Salafsky 1998). For example, consider the pompous question "Do transient aggregations of semi-feral *Gallus gallus* associated with adjacent subsistence agricultural establishments negatively impact propagule survival and juvenile recruitment of native arborescent vegetation within the management module, as compared with control exclosure plots?" While this wording might impress writers of government documents, less pompous phrasings do exist. Can you suggest one? How about "Do chicken flocks that wander into the reserve eat many seeds and seedlings of native plant species and cause plant regeneration to differ from that in comparable chicken-free areas?"

Likewise, if answering the question requires expensive and training-intensive technology, in many cases—although certainly not all—it's possible to propose a similar alternative that depends primarily on the proper use of the most versatile tools of all: your eyes, brain (including its accumulated knowledge of natural history), and hands. I don't mean to disparage the appropriate use of technology during the inquiry process. Nevertheless, evaluating many of the most urgent concerns confronting conservation professionals depends more on proper application of the inquiry process than on the use of technological marvels (box 3.1). For example, consider the management concern over the best way to enhance the recovery of a watershed affected by illegal gold mining (chapter 2). Some excellent questions generated by that concern—and complying with all the preceding criteria—would involve sophisticated technologies for analyzing soil chemistry and stream chemistry, almost certainly resulting in precise and objective answers. But with limited resources you might address the same concern by framing equally excellent questions that require straightforward and inexpensive methodologies such as sampling stream insects (chapter 8) or measuring the growth and survival of plant seedlings. Technology and technical language may increase the precision of your question and results, but add them only as necessary.

The question should be simple in another sense also. Limit the number of concerns or factors you include in a single inquiry. Especially if you're new to field work, you'll be tempted to explore all possible factors at once. For example, the thesis question of a very bright and eager student I know was something like "What's the effect of different combinations of substrate, type of container, amount of sun, type of fertilizer, watering schedule, place of origin, and planting season on the rate of germination of seeds of this species of medicinal herb?" Being only one person with a finite number of seeds at her disposal, she found it a bit difficult to come up with a definitive answer.

Framing Questions: Some Practice and Some Examples

Because skill at framing questions is the key to scientific inquiry and management, I strongly suggest that you go through the exercise of box 3.2 before reading any further.

Once more, in general terms, *all questions that are stimulated by observing one's surroundings are valid.* Still, some lead much more readily than others to firsthand inquiry and practical applications. Examples of "less than adequate" questions, by this measure, abound, and there's no need to list them here. Fortunately, examples of well-phrased questions also abound. I've culled a small sample of questions from the recent literature in applied ecology, all falling somewhere in the range between small-scale basic studies (figure 2.5) and urgent, large-scale conservation questions (figure 2.4). Sometimes the original idea wasn't explicitly presented as a question, so I've paraphrased the

Box 3.2. Practice with Framing Questions That Lead to Inquiries

If you went through the exercise of box 2.1, review the list of questions you generated. Carefully rephrase each one as necessary so that it's *answerable, comparative, alluring,* and *simple.* Make sure that you retain the basic concept or concern that stimulated the question originally as well as the spatial scale of that exercise.

Now practice framing "real-life" questions. Wander about outdoors, preferably in the protected area or other landscape where you work, and develop questions based on your real conservation concerns or on ideas for a possible field study. This time, of course, the questions could involve any scale of space and time, the only requirement being that each question should conform to the four criteria in this chapter. At the end of the exercise, review your questions—better yet, ask a colleague to review them—to make sure that there isn't an even better way to word them with respect to those criteria.

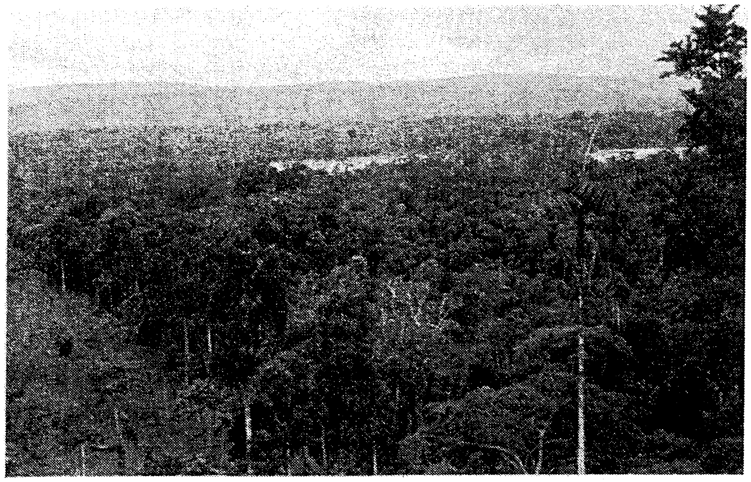

Figure 3.1.
A reserve border that experienced selective logging in the past (Napo Province, Ecuador).

author's writing a bit. In all cases, though, the idea conformed to most or all of the four guidelines discussed in the preceding sections. In all cases, results of inquiries initiated by these questions have already influenced, or could influence, the development of conservation and management guidelines:

1. Compared with unlogged forest, what is the effect of low-level, selective logging (figure 3.1) on bird assemblages (Thiollay 1992)?
2. Is there a substantial change in the local and regional diversity of native animals (e.g., birds, insects, spiders, lizards, earthworms, small mammals) when traditional shade-coffee plantations are converted to modern sun-coffee plantations (Perfecto et al. 1996)?
3. In the restoration of native vegetation on degraded lands, does setting out perches for birds change the arrival rate of viable seeds and thereby affect the recovery process (McClanahan and Wolfe 1993)?
4. What is the impact of trout introduction on the native fauna of cool-water streams, as compared to streams with no trout present (Flecker and Townsend 1994)?
5. Do populations of native tree species benefit more from the presence or absence of domestic livestock (Reid and Ellis 1995)?
6. Do roads and major trails affect the rate at which exotic, weedy plants invade natural areas (Tyser and Worley 1992)?[1]
7. In lowland wet forest reserves with dirt trails often used by visitors, is the runoff of surface water, and accompanying soil erosion, greater or lesser from trails than from the untrampled forest floor nearby (Wallin and Harden 1996)?
8. What is the relative physical impact that (a) horses, (b) llamas, and (c) humans have on trails and on rates of soil erosion (DeLuca et al. 1998)?
9. What is the relationship between numbers of hikers that pass along trails and the abundance or diversity of native birds (Riffell, Gutzwiller, and Anderson 1996; Miller, Knight, and Miller 1998)?