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THE SCIENCE OF THE CANOPY: WHO NEEDS THE INFORMATION AND HOW THEY CAN USE IT

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INTRODUCTION

This meeting is about science in the forest canopy, an exciting new field that has climbed in importance over the past decade or so. I am convinced that most canopy scientists are vitally concerned about what is happening to forests worldwide, and hope that their research can contribute to better forest conservation. But judging from the precarious state of the world's forests, this hope is likely to be unrequited unless canopy scientists are much more proactive in delivering their messages to policy-makers and the general public.

First of all, we need to recognize that science and policy provide two rather different approaches to reality. To paint the picture in stark terms, scientists tend to view research as an end in itself, driven by ideas or techniques. The scientific method often forces research to be reductionist, isolating factors to be manipulated by experiments. Scientific results are often presented with statistical degrees of certainty or reliability, and productive research typically leads to more questions, which need to be answered. Scientists tend to view themselves as an intellectually-elite segment of society, believing that science deserves support simply because it is scientific research; accountability is largely restricted to the cultural process of "peer review." It often seems that the relevance of the research to the needs of society is overwhelmed by the aura of the sanctity of the curiosity of the individual researcher. Ideally suited to carrying out research, scientists seldom are inclined to understand the pressures under which policy-makers work.

Public policy, on the other hand, addresses problems, and many of the activities of its practitioners seem little more than attempts to contain crises with inadequate resources. By definition, these policies are in the public eye and subject to public scrutiny so they cannot be too experimental. The primary aim of the top policy-makers within the resource management agencies is to acquire budgets and control information so that public comment is minimized or to ensure that such comment is favorable. Resource management policies are frequently determined by committees, which may or may not have the necessary competence to make meaningful value judgments. They must deal with the larger picture and are not able to indulge in the luxury of manipulating a single variable in an experiment; research results are only one of a multitude of factors that must be considered. Making policies about biodiversity certainly requires a basic understanding of science and a familiarity with the scientific community, but policy-makers are seldom scientists and do not have time to digest the detailed information that would enable them to make full use of the scientific advice. They are especially nervous about statistically reasoned analysis that underlines uncertainty (Warren 1993), preferring clear-cut guidance in black and white. Policy-making in biodiversity has not been accorded high status in the academic community and managers have typically not been accorded the intellectual status given to scientists engaged in research (though they are better paid!) While usually poorly equipped to carry out scientific research, policy-makers often have very clear ideas about the kind of information they require for developing resource management policies.

Thus the priests of the scientific and policy-making sub-cultures of modern society have never communicated very well with each other, as both have sought to protect their own power base and have tended to ignore how they might best be able to enhance that power base by reference to the other sub-culture. The situation is made more challenging because the concerns of society and the actions of the numerous other actors on the biodiversity stage are in constant and unpredictable flux, as is science. This dynamism helps explain why controversy is so pervasive in politically-sensitive fields such as biodiversity, where science often is used by official environmental agencies to underwrite inaction or to provide political reassurance. Science has a virtually infinite scope to redefine biodiversity issues "scientifically", to embrace constantly-increasing numbers of real-world variables, or to refocus the significance attached to those already acknowledged (Grove-White 1993). It follows that the same is true also of the scope for criticism and disagreement, over much more fundamental matters than extinction rates or energy flows through ecosystems.

HOW SCIENCE IS USED BY POLICY-MAKERS

The need for science pervades the policy-making arena. Senior civil servants need scien-

tific advice in preparing ideas for regulations, legislation, programs, projects, and budgets; legislators need scientific advice to translate these ideas into draft legislation; the various interest groups need science to help ensure that their concerns are built into the legislation and to support its passage through Congress, or at least influence management decisions; and science is needed to assess how policies, programs and projects are affecting biodiversity. How science is actually used in these various contexts depends very much on the users.

Generally speaking, biodiversity policy is based on science as interpreted by the non-scientist. Since policy-makers typically lack scientific expertise, their reaction to scientific information is often either highly critical, questioning the validity of the science as the basis for action, or overly-accepting, adopting the scientific data uncritically. The quality of the scientific information is likely to suffer in either case, but the policy-maker still requires the science to be presented in simple, easily-digested morsels even when such over-simplification will weaken the basis for decision-making. When it comes to complex principles such as the conservation of biodiversity and sustainable use of forest resources, where scientific and social factors are closely inter-related, it is not surprising that a scientifically-based consensus is so difficult to reach.

And of course, the managers on the ground will need advice on how the policy is to be implemented. Thus the views and practices of non-scientists exercise a considerable influence over the way scientific observations are used. Institutions such as the mass media and the law inevitably act as filters and mediators, affecting the public prominence of scientific aspects of biodiversity. Scientists dealing with such a complex topic as biodiversity therefore are mere contributors to a dialogue in which many other disciplines participate.

In a World Bank study of decision-making about diversity, Metrick and Weitzman (1994) found that both scientific and emotional elements play important roles in determining whether a species was put on the U.S. Endangered Species List, but that the scientific characteristics appear to have little influence on the way funds are actually spent by the Federal and State governments to address the problems of these species, as the emotional characteristics seem to dominate.

Concern about biodiversity was first crystallized not by governments responding to or using science, but rather by relatively poor and powerless NGOs and academics who mobilized their own science, and communicated it effectively through the mass media and direct mail campaigns (e.g., Wilson 1985; Myers 1985). But "official science" has been the effective measure of whether issues are "real" and are given attention by government policy-makers. Since biodiversity is unable to speak up for itself, it needs a stand-in, and in modern industrialized societies science often seems to be the only stand-in capable of commanding widespread legitimacy. However, scientists do not control how scientific evidence is used to influence public opinion. The mass media seem to demand a rough sort of balance between competing viewpoints and give a premium to controversy and the mediagenic, often leading to polarization. Thus information provided to the public by the mass media is often misleading; for example, while most of the global focus is on biodiversity loss in the tropical forest, the developed countries accounted for over 80 percent of global forest products in 1992, with the US alone earning three times more than the highest-exporting developing country (Indonesia). While the mass media focus on tropical tigers, rhinos, and pandas when extinction is mentioned, by far the greatest numbers of recorded extinctions have taken place in developed countries, namely the US and Australia (Groombridge 1992).

Keeping biodiversity on the public agenda requires overcoming at least three formidable problems (Tobin 1990). First, current practices that are depleting biodiversity often are extremely popular. The fact that the desire for consumption is far more powerful than the conservation-oriented advice of scientists should come as no particular surprise, as incentives to consume far outweigh incentives to conserve. A typical American meal travels 1,300 miles from farm field to dinner plate, while in much of Africa it is generally just a few hundred meters. The resource requirements of microwave-ready foods are about 10 times higher than those for preparing meals from scratch. It takes 94 times the amount of energy to obtain an out-of-season piece of fruit or vegetable from a foreign locale, and 30 times more from a local greenhouse, than if obtained in-season and locally produced. Yet, most of us act as if December strawberries are part of our birthright. As another example, a 1994 report on the Commission on Sustainable Development found that worldwide, the amount of money governments spent to support environmentally destructive behaviour amounted to US$1 trillion per year. Another indicator is the amount of money spent on advertising, basically encouraging people to consume more than they might otherwise consume. Globally, advertising budgets were expected to rise 7.4 percent in 1995 to US$364 billion, more than the annual

GNP of Australia or the Netherlands. McDonalds restaurants, for example, spent more than $425 million for advertising in 1990, and while the US was cutting its support to the World Food Program, designed to feed the starving masses in developing countries, Ultra Slim-Fast Diet Food was spending more than $77 million in advertising.

Second, no easily-identified opponent is available against which conservation forces can be rallied; unlike such headline-makers as Bhopal, the Exxon Valdez, and Chernobyl, no newsworthy disasters have yet linked human welfare to the loss of biodiversity. On the contrary, many people are making substantial profits from overexploiting biological resources, and those with the highest political profiles tend to be among those making the largest profits through overexploitation. It is apparent that the larger and the more immediate the prospects for gain, the greater the political power that is used to facilitate unlimited exploitation, often through mobilizing significant economic incentives provided by government. The private benefits from clearing the forests of Indonesia, for example, are much less than the public costs from the resulting forest fires, but this equation has little bearing on Indonesian forest policy dominated by logging interests.

And third, the loss of biodiversity has no immediately observable impact on lifestyles, especially those of people living in cities far removed from the biological resources which support their consumption. If we are losing dozens or hundreds of species per day, as many experts assert (and especially based on studies of the tropical forest canopy), then we are already living with the consequences of extinction without any discernible effects on our daily lives. And when scientists argue that efforts to conserve endangered species deserve especially high priority, it is difficult to link this argument directly with the human welfare issues of concern to policy-makers because these species have already been reduced to such low population levels that they usually can be used only as symbols.

Who are the "Customers" of Information from the Canopy?

Following this rather general introduction of the challenges of applying science to policy, it is perhaps worthwhile to identify some of the major "customers" or "consumers" of the results of the kind of research that is being done in the tropical forest canopy, or could be done there. A complete list of these could be quite extensive, but I will mention just seven main groups:

- **Other scientists**. This is probably the easiest group for most scientists to work with as they represent a peer group with clearly-defined rules of communication. They will be interested in your methodology, findings, data, and so forth published though the scientific literature and presented at scientific meetings. No great challenges are posed by this group, but they have little discernible impact on forest policy in most countries.
- **Foresters**. Foresters in the tropics generally are expected to be managing the forest estate to provide sustainable benefits, mainly economic, primarily to the central government and secondarily to local communities. They tend to focus on the rather out-moded concept of maximum sustainable yield, though some encouraging signs of a more enlightened approach are also becoming apparent. Thus at least some tropical foresters are looking at other uses, such as nuts, gums, and fruits harvested from the forest, other non-timber forest products, consumptive use of wildlife, recreational hunting, watershed values, medicinal plants, and carbon fixation. These foresters may be extremely interested in at least some of your research findings, especially if your results can be put in forest management terms.
- **National policy-makers.** Foresters, as well as scientists, typically operate in the context of national resource-management policy. Given the "boom-and-bust" cycle of tropical forest exploitation, these policy-makers are often responding to a moving target, and frequently are several years late in developing policy to respond to changing conditions. Such national policy-makers are concerned above all with national welfare, and they need to be convinced that policies are in the broad public benefit. They often may require economic elements in the advice they received.
- **International policy-makers**. The international policy-makers include investors, bilateral aid agencies, the multilateral development banks, the Global Environment Facility, UNEP, UNDP and so forth. These policy-makers may have very different perceptions from those at the national level, often seeking to identify global benefits that justify their investments. This is likely to be a group that is particularly interested in the kind of research that comes from the forest canopy.
- **The private sector**. The private sector is interested primarily in the bottom line: how much profit can they make? That said, many private sector firms are also interested in sustainability, and might be convinced that research in the tropical forest is worthy of investment because it provides useful informa-

tion to them over the long term. Biotechnology might be one such field, especially in regards to pharmaceuticals, biological controls of pests, and various chemical products from plants and animals in the tropical forest.

- **Conservation NGO's**. As mentioned above, the conservation of biodiversity has been led by NGO's, and they are anxious for information that will help support their conservation message. They will be quick to market your results when they support a conservation message, in a way that can be presented to the donating public.
- **The general public**. While the general public is rather vaguely in support of conservation of the tropical forest, especially if this does not require any particular sacrifice from them, the environment generally seems to be waning as an issue of public concern (though the recent spate of major forest fires, seemingly linked to both climate variables and inept forest management practices, may change this somewhat). The general public likes dramatic messages, as evidenced by the popular press response to at least some of the work in the canopy (and from forest fires). This is a good indication of market demand for the kind of work you are doing, and should be strongly encouraged. But this may require you to get some results out to the general public before they are supported with the kind of scientific rigor your peers require.

Research from the Canopy: What the World Needs

The participants in this symposium are far better qualified that I am to say what kind of research needs to be done. Even so, I would like to offer an outside perspective from the point of view of a customer of your information. Here are some of the main issues that I see emerging, from the perspective of an international conservation bureaucrat (and I expect to revise this list based on the results of this meeting):

- **Sustainable use.** A critical issue is how to ensure that any uses of forest products are sustainable. Much growth in forests happens in the canopy. What is the theoretical maximum timber yield for trees from the perspective of their biochemical efficiency in converting sunlight into wood? Can the results of canopy studies on productivity be put into practice by foresters? What can changes in the forest canopy tell managers about whether the system is being affected by exploitation?
- **Rates of change**. The rates of change in environmental conditions clearly are a critical issue, because managers need to respond to external changes differentially depending on these rates. Are changes unidirectional, or more cyclical? We need to seek ways of linking changes in relatively undisturbed forests with those in more disturbed areas. Thus the baseline established by the canopy studies may be helpful in determining these changes. What are the correlations with changes in other habitats, particularly coastal and marine habitats?
- **Climate changes**. Despite very considerable investment in research, the dynamics of climate change are still poorly understood, and the impacts of such changes on biodiversity are even more difficult to determine. The most significant threat to tropical forest from climate change is probably associated with drying trends, changes in rainfall patterns and seasonality which in turn could lead to changes in species distribution and composition. Webb and Bartlein (1992) reviewed climate change over the past 3 million years and the responses of biotic systems to these changes. They highlight the important role of the contrast between land and sea in translating the changing seasonal intensity of insulation into stronger and weaker monsoons and thus in producing periodic large changes in moisture balance in tropical climates. Tropical forest management strategies in a time of rapid climate change should emphasize ecosystem resilience, connectivity in an increasingly fragmented landscape, reducing the opening of forest canopies in logging operations and finding ways of using forest resources in an environmentally sustainable manner. The forest canopy may be the place where the biotic impacts of climate change can first be observed in the tropics, requiring baseline studies and longitudinal follow-up.
- **Extinction rates.** The issue of extinction continues to exercise the creativity of biologists. Current extinction rates are disturbingly high, perhaps four orders of magnitude higher than background extinction rates. But predicting which species are most at risk is an extremely difficult business (Lawton and May 1995). What can canopy studies contribute? Pimm (1996), based on two decades of working with Hawaiian birds, finds no clear single cause for their decline, concluding that synergistic interactions between multiple factors are responsible. The consequences of such synergisms is that once the rot begins, extinctions should be fast, furious, multifactoral, and in greater numbers than predicted from habitat destruction alone. One tactical consequence of this view "is that those who work with en-

dangered species in the habitat fragments that remain 50 years from now may have no more luck in disentangling the causes of particular extinction than our generation has," Pimm says, "Yet if we cannot identify simple causes of a species' decline, how can we prevent it?" What can canopy studies contribute to better understanding of this phenomenon?

- **Ecosystem integrity.** This has two very different senses: equilibrium under average conditions (where resistance to disturbance and speed of return to the equilibrium are used to measure reliance), and resilience under catastrophic conditions. The second definition emphasizes conditions far from any equilibrium in which instabilities can flip a system into another regime of behaviour. In this case the measurement of the resilience is the magnitude of disturbance that can be absorbed or accommodated before the system changes its structure by changing the variables and processes that control system behaviour. Holling and Meffe (1996) call that "ecosystem resilience" because its significance becomes clearly apparent for large-scale systems over long periods. The first definition focuses on efficiency, constancy, and predictability—attributes at the core of command-and-control desires for fail-safe design. The second focuses on persistence, change, and unpredictability—attributes embraced by an adaptive management philosophy. What can work in the canopy tell us about these two rather different characteristics, and what management approaches will work when?
- **Interactions among species.** Single-species approaches to conservation ignore the critical role of interactions. The interactions between species are incorporated into conserving biodiversity. Four major ecological effects are of concern: the loss of keystone species may lead to the disruption of the organization of a community and subsequent loss of species; the functioning of ecosystems may change because soil fertility and the cycling of major nutrients through the biosphere depend heavily on interactions among species; the invasion of alien species can disrupt ecosystems in many ways and lead to extinctions, as has been observed on many oceanic islands; and the spread of other species due to changes in environmental conditions, such as forest fragmentation, may lead to the formation of new interactions that may be detrimental to the survival of some populations and species (Thompson 1996). What can work in the canopy tells us about whether these suspected effects are in fact taking place.
- **Disturbance.** Anyone who has camped in a rainforest will have been startled from time to time by a nearby tree crashing to the ground. Far from destroying the forest, such natural disturbances provide opportunities for regeneration. How long does it take a tropical rainforest to turn over? Shouldn't we have a canopy crane in a disturbed forest?

Conclusions

All of the above lead to several conclusions:

- First, the longer canopy research is carried out, the more valuable it will become, generating information about the changes in the canopy that might be correlated with changes in the larger environment.
- Second, canopy research is going to be most useful when the findings from the several research sites can be compared: this calls for some standardization of research methodologies.
- Third, canopy research is going to be most useful when it is part of larger research efforts that allow comparisons between different levels of disturbance, different management regimes, and so forth.
- Fourth, to build the external support needed to maintain funding for canopy research, due attention needs to be given to packaging and marketing of your results. The various international conventions, such as the Convention on Biological Diversity and the Framework Convention on Climate Change, offer one important channel, but many others also exist.

The limits of current knowledge about forest ecosystems do not preclude action now. Because of the profound, pervasive, and accelerating impacts of modern society on forest biodiversity, the effective *in situ* conservation of such diversity depends more fundamentally on political choices about resource use and benefit sharing than on the refinement of such scientific knowledge as we do have. But how can the information generated by research in the forest canopy be used most effectively to influence politcal choices?

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