Science and the Right to Information

The many streams of human knowledge have been shaped by an interplay of seeking after truth and telling calculated lies. Of these, the folk and classical streams cannot effectively discriminate empirically valid knowledge from beliefs, and have grown slowly. Science is notably an organised enterprise of scepticism, anchoring itself firmly on the bedrock of empirical facts, thereby ensuring that deliberate manipulation of information is quickly exposed and eliminated. Official knowledge, though claiming to be science based, permits itself to be manipulated by vested interests, by discouraging scrutiny As a result, much of the information base for managing India's environment is incomplete, outdated, or downright bogus The only way to correct this is to expose it to public scrutiny. The new Right to Information Act makes this possible The tools of information and communication technology can facilitate such scrutiny by making available all relevant information, in full detail, on a publicly accessible website Together, these developments present a tremendous opportunity to replace the current bureaucratic "control and command" by a "share and inform" approach.

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In March 2005, the nation was shocked to learn that the king of beasts no longer roamed in the tiger reserve of Sariska, although the authorities had been insisting that there were 17 of them still at large. In fact, a Central Bureau of Investigation enquiry revealed that the last tiger had been poached several months earlier, perhaps in August 2004. Something is obviously wrong with the system of protecting this flagship species. Equally clearly, much is amiss with the system of assessing tiger numbers and sharing this information with the public.

Significantly, this is happening at a time when Indians are taking pride in the fact that we have become noteworthy actors in the newly unfolding information age. Evidently, while we are making good money processing information for banks and hospitals abroad, we are doing a poor job of managing information on our own heritage of natural resources. While we have passed the Right to Information Act, at least some of the information to which we now have a right, is flawed, perhaps fraudulent The exercise of counting tigers, it would appear, has been dedicated to manipulating public opinion, and in the process, science, and its values of openness and honesty, have fallen by the wayside. It is time then to reflect on how we view and nurture knowledge in its many streams; the multifarious folk traditions, the rich classical traditions like Ayurved and Yunani, and the powerhouse of modern scientific knowledge It is also vital to assess how we deploy all this knowledge towards managing our land, our waters, our atmosphere, and the diversity of life around us

A Knowing-Scheming Animal

Humans are superbly adept at processing information Indeed we owe our dominance of earth to our abilities to figure things out, to our occupation of the "cognitive niche" [Pinker 1997; Tooby and DeVore 1987]. People attempt to reach their goals by constructing complex chains of behaviour in response to the situations they face Such behaviours are planned on the basis of mental models of cause and effect in the world around us That makes us the only animal to figure out that if we drive a herd of elephants over a precipice, we would get a lot of meat by walking down to the bottom of a cliff that is out of sight. Such models are learnt during a lifetime and communicated through the medium of language, permitting accumulation of knowledge over generations. These capabilities enable us to undertake deliberate actions, and to profoundly modify the world around us to our own ends.

From time to time, such deliberate actions ensure long-term conservation of natural resources, rendering man the only "prudent" species. In a landmark paper Slobodkin (1968) asked if there were any prudent animals. By prudent he meant predators that exhibit restraints on harvests such that long-term yields from the prey populations are enhanced at the cost of immediate harvests. His answer was in the negative. Animals always seem to behave as optimal foragers, concentrating at any time on prey that maximises the energy or nutrient returns per unit time, or minimises the risks incurred. Animals leave some species, or age class, or patches of prey alone, only because they have better options Humans too behave as optimal foragers much of the time [Borgerhoff-Mulder 1988]. In the Torres Strait, fishing may be stopped in localities where fish yields are observed to have declined, or in parts of New Guinea, the hunting of Birds of Paradise may be temporarily abandoned if their population declines [Eaton 1985; Nietschmann 1985]. These responses may merely indicate that the returns from that prey species or those localities are lower than returns possible from alternative species or localities. But in other cases humans seem to refrain from harvesting resources that might provide higher returns than the alternatives exploited. Thus, residents of the village Kokre Bellur near Bangalore have been strictly protecting storks and pelicans breeding in the midst of their village for centuries, although the same birds may be hunted outside the breeding season. Obviously, the nesting birds are far easier prey, which is nevertheless left alone, very likely enhancing the long-term availability of the prey population and their guano. Modern resource management practices too include examples of deliberate restraints on resource harvests, whether these are mesh size regulations, closed seasons, or protection to endangered species [Gadgil and Berkes 1991; Gadgil, Berkes and Folke 1993].

Perhaps, such prudent behaviour is exceptional. For, man's chief occupation seems to be extermination of other animals and plants, often undertaken very deliberately. Large-scale felling of forests in the north-eastern US and the massacre of hundreds of thousands of buffaloes of the prairies by early European colonisers of the Americas were instances of deliberate destruction. Yet, these destructive acts might be presented in a very different light. After all, man is very capable, not only of spelling out what he intends, but also of elaborate cheating, and therefore of pursuing a hidden agenda, quite at variance with the declared agenda [Pinker 1997]. Thus the burning, along with every creature of the great Khandava forest, on the site of present-day Delhi, was declared as an offering to the fire god, Agni. It was most likely motivated by the need to displace the shifting cultivating Nagas occupying that forest and clear the land for the invading pastoral Pandavas and Kauravas [Karve 1967]. Similarly, the British reservation of huge tracts of community-managed forests in the 19th century was justified as necessary for forest conservation. It was probably motivated by the desire to acquire very cheaply wood to support the expansion of railways. Indeed, as a British revenue administration official of Madras presidency put it, this was "confiscation, not conservation" [Gadgil and Guha 1992]. In the course of growing knowledge, then, humans accumulate and disseminate sound information to enable them to effectively control the world around them, and, at the same time, deliberately using misleading information to manipulate other human beings.

Evolution of Knowledge Systems

It is fascinating to trace this interplay of seeking after truth and propagating calculated lies in man's pursuit of knowledge. One may distinguish for this purpose three broad streams of knowledge, namely, folk, classical and scientific. The folk knowledge systems are the oldest, and based on opportunistic observations and trial and error experiments, as well as "divine revelations". Folk knowledge is subject to limited and not very systematic scrutiny, and may include elements consciously introduced to mislead. As a result, it constitutes a commingling of empirically valid knowledge and unsustainable beliefs. The classical knowledge systems such as Ayurved involve much more systematically organised information. They have drawn extensively on the folk knowledge; indeed Ayurvedic texts recommend that the physicians learn from cowherds, hunters, sages, consumers of roots and tubers, and other forest dwellers who are intimately familiar with herbs. This counsel, however, clashes with the belief stated in these same texts that all knowledge of Ayurved flows from gods who handed it to the sages. In human hands this knowledge is only supposed to degrade. This is an authoritarian view of knowledge, limiting, if not entirely closing the door on scrutiny and further improvement in knowledge on the basis of empirical observations and experimentation [Garde 1956].

Modern science has elaborated a more effective way of growing knowledge. This involves rejection of all authority other than that of empirical facts. Science has thus firmly anchored itself on to the hard rock of facts. Simply put, the methodology of science entails observing facts directly, often with the help of carefully designed experiments, discerning patterns, inferring processes that give rise to the observed patterns, making models of the working of the system under consideration, formulating hypotheses about the system, making predictions, verifying predictions through fresh observations of facts, revising models of the working of the system, and then making new predictions, in an ever-continuing process. In the march of science anybody is welcome to challenge any assertion: whether it be of facts supposedly observed, or of models of how the system works. Along with rejection of all authority, science has given up claims of arriving at any absolute Truth. Science deals in knowledge that is always treated as provisional, that is open to being supplanted by newer and more effective observations and theories [Bernal 1939, 1954].

Scepticism is thus at the very heart of scientific inquiry. Therefore, the main ingredients of the scientific enterprise are:
- Open access to all facts and inferences,
- Rejection of all authority other than that of empirical facts, and
- Welcoming all interested parties to question all assertions as to facts as well as logic.

It is this openness that has ensured that in science, the proportion of empirically sound to unsound information is very high, and any deliberate manipulation of information is quickly exposed and weeded out. In consequence, the rate of growth of scientific information has been continually accelerating. On the other hand, folk and classical knowledge has grown rather slowly; for instance, Ayurved has remained largely stagnant over last 1,500 years.

To these three major streams of knowledge, one may add a fourth category, the official knowledge system. Official knowledge claims to be based on systematically organised, properly validated information in the spirit of modern science. Yet by discouraging scrutiny, it permits itself to be manipulated by a variety of vested interests. It therefore often ends up with a low proportion of empirically sound to unsound information.

Table 1: Characteristics of Major Streams of Knowledge

Knowledge System	Sources	Scrutiny	Degree of Deliberate Manipulation	Proportion of Empirically Sound: Unsound Information	Rate of Growth
Folk	Empirical observation, revelation	Limited	Limited	Moderate	Slow
Classical	Empirical observation, revelation	Limited	Limited to substantial	Moderate	Slow
Scientific	Empirical of observation	Encouraged	Very limited to absent	Very high	Very fast
Official	Empirical observation, authority	Discouraged	Limited to substantial	Moderate	Moderate

Table 1 summarises the characteristics of these four knowledge systems.

Systems: Simple and Complex

Experimentation, involving extensive replication of conditions where just one or a few parameters are permitted to vary at a time, is at the heart of the scientific method. It has been outstandingly successful in the case of simpler physical and chemical systems that can be specified adequately in terms of a small number of parameters. This has permitted the formulation of a number of generalisations, of universally applicable laws with considerable predictive power. As a result, our understanding of simpler systems has progressed enormously.

But with the more complex systems, the situation is different. Complex systems characteristically require a large number of parameters for their specification. As a corollary, each manifestation of the system tends to be unique. Thus, every patch of forest harbours a set of animal species slightly different from every other patch in the world, or every cyclone in the Arabian Sea is different from every other. Since the experimental method depends on the experimenters' ability to control all relevant parameters and to replicate conditions at will, it cannot be readily applied in the study of complex systems like ecosystems [Shrader-Frechette and McCoy 1993].

The experience of a group of Bangalore-based ecologists investigating the fate of wild 'amla' *(Phyllanthus emblica)* populations on the nearby B R T Hills provides an interesting example. Their hypothesis was that the regeneration of amla is governed by the amount of fruit collected for commercial use, and that the prevailing low levels of regeneration were related to excessive harvests. So they laid out statistically well-designed experiments to test the influence of different levels of harvests. The local Soliga tribals felt that these experiments would yield no results of interest, because, according to their understanding of the ecosystem based on many years of first hand observations, the levels of regeneration were primarily influenced by forest fires. *Amla* seeds required fire to germinate well, and the Soligas felt that low levels of regeneration were related to suppression of forest fires in recent years. The scientists did not initially give credence to this suggestion and continued their experiments. Only later did they come to the conclusion that the Soligas were indeed right (K S Murali personal communication).

Thus, since it is difficult to discern what the relevant parameters are in a complex system, it is hard to design meaningful experiments. This does not, of course, mean that experiments have no place in the study of complex systems. But, the BRT hills example points to the fact that field observations, including historical observations are vital to the understanding of such systems. Such field observations are at the heart of the folk knowledge systems, often dealing with highly complex systems. Official knowledge too often deals with complex systems. Hence, a great deal of official information, e g, depth of underground water table, level of pollutants in factory effluents or the number of tigers, also depends on field observations. As Latour (1986) points out, the strength of the modern systems of knowledge lies in the span and potency of the networks they are able to assemble. The scientific knowledge system backed by a strong network makes justifiable claims to validity. The official knowledge system too has the backing of a strong network, and is therefore able to claim credence despite its weaknesses. But the folk knowledge totally lacks the support of a network. Hence, a careful assessment of folk knowledge and its assimilation in the network of scientific knowledge promises to greatly enrich our understanding of ecology and other sciences of complex systems.

Official Knowledge

Science activists have been rightly concerned with eliminating superstitious beliefs that do not stand up to scrutiny. In the same scientific spirit of challenging all authority, they also need to put under a scanner the contents of the official stream of knowledge. Nothing brings this home so well as the recent tiger crisis in Sariska. Authorities of our tiger reserves have been attempting since 1973 to come up with exact tiger numbers based on the so-called "total pugmark count". There are several possible sources of errors in such a census of tigers:
(1) Pugmarks of some tigers would never be encountered. (2) Different pugmarks of the same tiger may vary so much that they may be assigned to different individuals. (3) Some pugmarks of distinct tigers may be so similar as to be assigned to the same individual. (4) Levels of these errors may differ with locality, season, terrain, tiger densities, and many other factors.

This implies that it would inevitably be difficult to arrive at exact tiger numbers based on total pugmark counts [Karanth and Nichols 2002]. Such difficulties are universal, especially in the study of complex systems, where all signals are masked by some noise. The scientific skill lies in estimating and minimising the noise levels. Thus, it is imperative that one estimates the extent of various sources of errors in arriving at tiger numbers. Based on these, one should come up with not just one specific number, but also a range with a statement of the likelihood that the actual numbers will fall within that range. Unfortunately, the official knowledge stream has the serious weakness of pretending that the authorities are in possession of the whole truth, that there is no question of error, in the official, "authoritative" information being handed out. For instance, when our remote sensing agencies provide maps of land cover based on the interpretation of satellite images, they ought to provide a "confusion matrix", i e, a statement of likelihood of errors in their interpretations. But there is a tendency not to do so. This official approach is entirely incompatible with the scientific discipline of never making claims that cannot be fully supported by facts at hand.

But if this is ignored, and a single number provided as if that is a precise estimate, there is every danger that any lower number arrived at subsequently would be taken to imply a decline tiger numbers. If, further, there were a tendency to judge the performance of tiger reserve managers on the basis of the supposedly exact number of tigers in the area under their charge, then the managers would be inclined to manipulate the data and project a picture of continually increasing numbers of tigers. Such a tendency could be checked if there was in place a system of public scrutiny of the veracity of the numbers being declared. However, no such system has been in operation, so that tendencies to manipulate data have gone on unimpeded. This has, in all probability, been occurring in many tiger reserves. We now have concrete evidence that it did happen in Sariska, where the publicly declared numbers have been decidedly inflated. An unfortunate consequence of dissemination of manipulated data has been a failure to recognise signs of decline in tiger numbers, till a public outcry forced the authorities to subject official statistics to independent scrutiny. This was done, firstly, through a CBI enquiry, and secondly, through the prime minister's office setting up an independent tiger task force. The task force had access to the information available with the field staff and put together the picture in Table 2.

Counting Tigers Reliably

To reiterate, use of some systematic procedures and statements, often associated with much of official statistics, such as the tiger pugmark count, does not by itself produce scientific, valid, knowledge. The hallmark of scientific knowledge is continual open scrutiny that ensures that it is firmly anchored on to the bedrock of hard facts. Given the complexity of natural ecosystems supporting tigers, it is tricky to arrive at definitive facts. Therefore, it is appropriate that multiple lines of evidence with information coming from a diversity of sources, including local community members, are tapped, and the likely validity of conclusions constantly assessed. Furthermore, scientists, local community members and all other interested citizens should be made fully aware of all the lines of evidence being used and have an opportunity to point out any misgivings. It is such an open system of continual bringing together of all pertinent data and open questioning by all who have some pertinent information that is the key to the success of modem science and these lessons should be applied to tiger counting as well.

Bamboos

Consider bamboos as another case in point. I became involved in the investigating bamboos at the instance of the government of Karnataka wishing to examine the claims of the basket-weavers that paper industry was destroying the very basis of their livelihoods [Gadgil and Prasad 1978; Prasad and Gadgil 1981]. Bamboos are light demanders reach the forest canopy in a single spurt of growth over a few months of the monsoon. They achieve this feat of coupling a high rate of growth with the height of a tree by producing hollow culms strengthened periodically by horizontal septa. The culm walls are rich in cellulose and derive their high tensile strength, comparable to that of steel, from the presence of very long, longitudinally aligned cellulose fibers. This renders bamboos excellent structural materials that can be worked easily even with the most primitive tools. So bamboos have been used to fashion bows and arrows, mats and flutes, baskets and windows, water pipes and seed drills, and, in modern times, paper and boards. Being grasses bamboos have green stems that fix carbon. Hence, their pattern of growth differs radically from that of other trees. In a normal forest, tree growth is predominantly in height of the stem, so that the proportion of photosynthetic tissue to the structural tissue steadily declines with increase in size, leading to a decline in the relative growth rate. The growth curve of a tree therefore conforms to the sigmoidal pattern, being slow at first, gathering pace at middle sizes and slowing down again. But, once a bamboo clump has passed through the seedling and bush stage, it begins to produce culms of the full adult height that reach the top of the canopy in a single burst of growth. Beyond this stage, the growth of a bamboo plant is essentially by radial enlargement of the underground rhizome and addition of more and more culms, all of the same form. The proportion of photosynthetic tissue to the total biomass thus changes very little once a bamboo clump has been established. The bamboo clump as a whole therefore exhibits an exponential pattern of growth, i e, the more culms it has, the more culms it adds in any given year. This simple fact, critical to deciding on the optimal number of culms to be harvested from a clump of any size, had not been realised before I initiated my studies on bamboos in 1975.

Table 2: Tiger Population Estimates in Sariska Tiger Reserve

Year	1998	1999	2000	2001	2002	2003	2004
Tiger population (official census)	24	26	26	26	27	26	17
Tiger sightings by staff	17	6	5	3	0	1	0

Note: Here tiger sightings by staff refer to number of distinct animals present as judged by field staff.
Source: Tiger Task Force 2005

Big Bang Flowering

Notably, 70 out of 72 of the Indian bamboo species possess a long period of vegetative growth followed by a single burst of reproduction, ending in death. Eight of these 70 species exhibit synchronised seeding of all clumps over an area of several hundred square kilometres. *Bambusa arundinacea*, a mainstay of paper industry of Western Ghats exhibits such synchronised mass seeding, at intervals of about 45 years. The copious seed production of this species may reach 100 quintals per hectare – a veritable bonanza. This spectacle of nature has attracted people's attention since time immemorial. In fact, many villagers of Western Ghats date various events such births and marriages in relation to the last mast seeding of bamboos. There is abundant historical evidence of these events in written documents as well, including the district gazetteers of 19th century [Campbell 1883; Gadgil and Prasad 1984].

Industrial Uses

The long cellulose fibres of bamboo render it an ideal raw material for paper production. The first paper mill based on bamboo of the Western Ghats, the Mysore Paper Mills (MPM) was established at Bhadravati in Karnataka in 1937; others have followed. These mills were expected to use bamboo resources on a sustained yield basis. When the MPM was established, a survey of the bamboo resources of the division was carried out, and the yield annually obtainable on a sustained basis was estimated at 1,00,000 tonnes. The yield estimates, however, did not take account of the periodic gregarious flowering of bamboos. This, of course, is thoroughly unscientific since this phenomenon is well known and documented. Much of the bamboo stock of Bhadravati division flowered and died in 1954-55, a time which coincided with an increase in the capacity of the mill to that required larger bamboo requirements. Following the flowering, MPM started exploiting bamboo resources of many other divisions rich in bamboo. Bamboo regeneration is expected to take 10-15 years and MPM should have been in a position to switch back to Bhadravati division by 1965-70. The regeneration, however, failed almost totally, and MPM continued to exploit bamboo from other divisions. The sustained yield calculations have obviously been wide off the mark.

West Coast Paper Mills (WCPM) at Dandeli was the second paper mill to be established in Karnataka in 1958. The mill was accorded a concessional area in the Uttara Kannada and adjacent regions. The sustained yield for this concessional area was estimated at 1,50,000 tonnes a year, and the mill was started with a requirement of about one-half the expected yield. Again, no account had been taken of the possibility of gregarious flowering, which began in 1959 in Uttara Kannada just as the mill swung into production. Thereafter, the annual yield averaged only about 40,000 tonnes. WCPM was, therefore, forced to bring in bamboo not only from the neighbouring states of Kerala, Tamil Nadu, Maharashtra and Andhra Pradesh, but from as far away as Meghalaya [Prasad and Gadgil 1981].

Declining Stocks

There thus appears to have been a consistent overestimate of the yield obtainable from the bamboo stocks of Karnataka ever since industrial consumption began in 1937. A working group of the State Council for Science and Technology asked Narendra Prasad and me to look into this problem and assess afresh the resource position on the basis of the data available from the State Forest Resources Survey, the WCPM and fresh fieldwork. These field studies revealed the Forest Resources Survey figures to be overestimates by a large margin by a factor of 10. In fact, there were some very gross errors. Thus, the area assigned to the township of WCPM still showed high levels of bamboo stocks in a survey following its disforestation, simply because it had copied figures, number by number, from an earlier working plan. The estimate we arrived at for Karnataka as a whole after correcting for these overestimates was that only ~1,33,000 tonnes of sustained yield of bamboos was available on an annual basis, in comparison with the total yearly harvest of well over 1,60,000 tonnes. The result, of course, has been a continual decline in the bamboo stocks [Prasad and Gadgil 1981].

It should be noted that we could assess the bamboo stocks because detailed information disaggregated to the level of forest compartments was available. This would not have been possible if we had access only to highly aggregated data such as at a district or division level. By and large, such official statistics as are available to the general public are supplied at a highly aggregated level, e g, the Forest Survey of India data at district levels and in terms of very gross categories such as closed and open canopy forest. It is difficult for individuals, or even professional groups to assess the validity of such information. Since real progress is possible only when a number of actors can be involved in scrutinising the data and correcting any errors, it is essential that, in the new era of people's right to information, official statistics be made available in a timely fashion and at a highly disaggregated level.

Manipulating Bamboo Clumps

Our studies brought out many other weaknesses as well in the so-called scientific management of the bamboo resources. Thus, the regime prescribing the number of culms to be extracted from bamboo clumps of different sizes has to be based on a model of the growth of the bamboo clump. This was flawed because the model being used by the forest department failed to appreciate the exponential nature of the growth of a bamboo clump. Consequently, it did not allow for the continually increasing growth potential of every bamboo clump and prescribed excessive harvests from smaller sized clumps. Furthermore, WCPM's sylvicultural practices involved cleaning of the thorny covering that develops naturally at the base of a bamboo clump, especially in the case of *Bambusa arundinacea*. This "clump cleaning" operation was meant to decongest the clump and promote better growth of the new shoots. Our studies showed this practice to be counter-productive, for removal of the thorny covering rendered the young shoots readily accessible to grazing by a whole range of animals, including porcupines, wild pigs, monkeys and domestic livestock.

This brings up the theme of people's knowledge. Our studies attempted to understand the practices followed by, and investigate the relative impacts of the rural as well as the industrial sector. We discovered that the villagers never cut the bamboo culms right at the base. Rather, they left the thorny covering of the clump in tact and cut the bamboos at a height of about a metre and a half. In fact, our conversations revealed that the villagers were fully aware of the problems caused by clump cleaning and made sure that their own practices did not expose the new shoots to grazing [Prasad and Gadgil 1981].

Science as an Inclusive Enterprise

Clearly then the so-called scientific management of bamboo resources, as that of tiger populations, is riddled with problems. These are not isolated examples; in fact, the entire management of natural resources of the country, including the vital resource of water, is grounded in a flawed model. It is true that this management follows certain systematic procedures; but science is not a matter just of systematic procedures. Rather it is a system of continual open scrutiny of the procedures being employed towards any given set of objectives, such as estimation of bamboo stocks and yields that can be sustained, or an assessment of tiger numbers, and of the level of reliability of the results these procedures produce. In fact, the main ingredients of the scientific enterprise, namely, (a) open access to all facts and inferences, (b) rejection of all authority other than that of empirical facts, and (c) welcoming all interested parties to question all assertions as to facts as well as logic, have all been missing in the so-called scientific management of the natural resources of the country. In this enterprise there is no tradition of transparency, of sharing of the results, the methodology employed to arrive at them and the logic followed in the deductions.

A truly scientific enterprise would treat documents such as Forest Working Plans as scientific documents to be made available for peer review by all interested parties, not as official documents to be kept away from the public gaze. The yields expected to be realised, and the stocks expected to be left behind after the harvests would be treated as hypotheses to be tested. If the yields do not materialise, or the stocks are not sustained, then a scientific enterprise would acknowledge that there are obvious errors of fact or logic, and attempt to look for and correct them. It would also try to bring on board all interested parties, not just the official machinery in the effort to understand the mistakes and correct them. None of this happens today, and it is imperative that we devise ways of injecting the democratic, inclusive culture of science in the management of India's natural resources.

Adaptive Management

We not only need to bring on board scientists, but the country's barefoot ecologists as well. For there is abundant evidence that given the nature of complex ecological systems, scientists too have a limited understanding of their functioning [Hilborn and

Ludwig 1993; Ludwig, Hilborn and Walters 1993]. The history of the Keoladev Ghana wetland at Bharatpur, home to numerous species of resident and migratory water birds provides an excellent example. The late Salim Ali and his co-workers spent decades studying this ecosystem. As a result of this work, Salim Ali was convinced that the ecosystem would benefit as a water bird habitat by the exclusion of buffalo grazing. The government accepted this recommendation, and, with the constitution of a national park in 1982, all grazing was banned. The result was a complete surprise. In the absence of buffaloes, a grass, *Paspalum* grew unchecked and choked the wetland, rendering it a far poorer habitat for the water birds [Vijayan 1987].

Scientists therefore advocate that ecosystem management must be flexible and at all times ready to make adjustments on the basis of continual monitoring of ongoing changes. In contrast, the government authorities made a rigid decision to permanently ban all grazing and minor forest produce collection from Keoladev Ghana, and having once committed themselves have felt obliged to continue the ban, even though it is clear that buffalo grazing, in fact, helps enhance habitat quality for the water birds. The emerging scientific philosophy therefore is to shift to a regime embodying systematic experimentation with more fine tuned prescriptions. Under such a regime, stoppage of grazing would have been tried out in one portion of the wetland, the effects monitored and the ban on grazing either extended or withdrawn depending on the consequences observed. This would be a flexible, knowledge based approach, a system of "adaptive management" appropriate to the new information age, and in complete harmony with our strengthening democratic institutions [Walters 1986].

People's Knowledge

The practice of adaptive management calls for detailed, locality specific understanding of the ecological systems. Much of the pertinent information on the status and dynamics of the local ecosystems, as well as uses of their components, resides with people who still depend on it for their day-to-day sustenance. In fact, the Keoladev Ghana story offers an excellent example of the relevance of people's ecological knowledge. The Siberian crane is one of the flagship species for which this wetland is being managed. Yet the numbers of these migrant birds dwindled in the years following the constitution of the national park in 1982. In an attempt to understand what people know of this ecosystem, we undertook the preparation of a 'People's Biodiversity Register' (PBR) at a village called Aghapur adjoining Keoladev Ghana during 1996-97 [Gadgil et al 2000]. The residents of Aghapur suggest that the national park regulations which prevent people from digging for roots of 'khas' grass have resulted in compacting of soil, making it harder for the Siberian Cranes to get at underground tubres and corms which are an important ingredient of their diet. Whether this is the primary cause for a decline in the visits by Siberian Cranes must, of course, be assessed; nevertheless, this is a plausible hypothesis that must be considered in developing a management plan for this wetland.

The recently enacted Biological Diversity Act provides excellent opportunities to bring together people's knowledge with scientific knowledge. This act aims to promote conservation, sustainable use and equitable sharing of benefits of India's biodiversity resources. With this in view it provides for the establishment of a National Biodiversity Authority (NBA), State Biodiversity Boards (SBB) and Biodiversity Management Committees (BMC) at the level of panchayats, municipalities and city corporations. The NBA is authorised to scrutinise all intellectual property rights related applications and ensure that they properly acknowledge the contributions of providers of indigenous knowledge. NBA is expected to consult all local BMCs in this respect and to ensure appropriate arrangements for equitable sharing of benefits.

While there are many significant initiatives such as joint forest management and watershed development towards decentralisation of ecosystem management, none of the institutions set up for the purpose have a statutory backing. The BMCs have the required legislative support and should therefore be in a position to strike roots more effectively. Most significantly, BMCs would serve to take science down to the grassroots, since, the rules lay down that "The main function of the BMC is to prepare People's Biodiversity Register (PBR) in consultation with local people. The Register shall contain comprehensive information on availability and knowledge of local biological resources, their medicinal or any other use or any other traditional knowledge associated with them."

A Cooperative Enterprise

Manifestly, local people must be at the centre stage of the PBR exercises to do justice to the task at hand. In any event, we simply do not have enough technical experts to man such an endeavour on their own. Therefore, the experts will have to work hand in hand with actors from many different segments of the society, from every village and town, from every fishing community, from every tribal hamlet, from every camp of herders. The network will have to include teachers and students from local schools and colleges, as well as local community leaders, government officials, researchers, and workers of voluntary agencies. Given their broad scope, the PBR exercises may be viewed as comprising two closely interwoven strands. The first of these strands may focus on the less structured, less fully shared information, primarily generated by local community members and community-based organisations such as Yuvak Mandalis and Mahila Mandalis. The second strand will concern the more structured, shared information, and local educational institutions, especially students of 8th, 9th and 11th standards, as also of undergraduate colleges, might play a key role in generating such information. For this purpose, they may work under the supervision of study groups set up by the biodiversity management committees for this purpose. Putting together the student contributions, along with the material generated by local community members, the study groups may compile the PBRs that should be ultimately put up to the gram sabha, or other equivalent assemblies of people for final approval. Special measures would have to be instituted to record and manage items of people's knowledge that they may wish to keep confidential. In fact, much more thinking needs to go into devising the appropriate systems for this purpose of managing information that has possible implications in terms of intellectual property rights. The PBR exercise will then be an innovative enterprise bringing together knowledge of the local people with scientific knowledge.

Environmental Education Projects

Apart from possible involvement in PBR exercises, India's student body is becoming engaged in environmental monitoring activities on a much broader scale as a consequence of the

Supreme Court order dated November 22, 1991: "We accept on principle that through the medium of education, awareness of the environment and its problems related to pollution should be taught as a compulsory subject". The recent National Curriculum Framework Review has suggested that this is best accomplished by infusing the teaching of environmental education in the form of activity-based projects in all subjects (NCERT 2005). Given the tremendous diversity of environmental regimes, such activities have to be tailored to time and locality specific contexts. Many of these activities should ideally be elaborated in the form of questions designed to test specific hypotheses. In this case, the standard scientific approach of conducting controlled experiments has limited application. Hence, in complex systems such as ecosystems, advancement of knowledge has to take another route – that of the comparative method, taking advantage of natural experiments. The comparative method is based on compiling information on two or more systems that differ from each other in a few features, generating hypotheses about the effect of such factors and testing them. For instance, lichens, symbiotic associations of algae and fungi that grow on rocks or tree trunks are known to be sensitive to air quality. India has a wealth of species that have not been studied from this perspective. We may hypothesise that species sensitive to air pollution would possess certain attributes, e g, be of a leafy, rather than crust-like form. Such a hypothesis may be tested by comparing lichen floras on the trunks of the same species of trees growing on roads carrying heavy traffic and elsewhere where the air is clean.

Recording New Facts

Since science has made limited advances in understanding of the complex systems, new facts are being continually added to our knowledge of such systems. Even non-scientists may participate in this adventure. Thus, amateur astronomers find new comets and asteroids from time to time, and amateur bird watchers routinely publish lists of birds from new localities. As a matter of fact, common people close to the natural world, such as the Soliga tribals of B R T Hills, have with them an enormous store of facts unrecorded in scientific literature. This is why high school or college students and teachers too can contribute to enriching our scientific understanding of the environment. Indeed, systematic recording of such facts by high school and college students could help flesh out the picture of the state of India's environment; the students could engage not only in recording basic facts, but attempt to discern emergent patterns and understand underlying processes. This would be a most worthwhile learning experience as well.

A Comprehensive Database

Today we have a dearth of quality information on state of India's environment. Of course, a large amount of information is collected as government statistics, for example on the depth of the underground water table. However, such information is quite incomplete, often faulty, outdated, and largely inaccessible to the public. Yet, depletion of groundwater is a truly vital issue. Such information is readily available everywhere from observations on open wells, and from experiences of people digging bore-wells. It is quite feasible to compile such information locally, through student projects. The projects could be so designed as to keep the information updated and then feed it into a comprehensive database.

Such information may be collected on a great diversity of themes ranging over physical, chemical, biological parameters to social, political, legal issues. These may pertain to soils, minerals, waters, natural, semi-natural and man-made habitats and biological communities. They may concern human activities such as hunting, fishing, agriculture, animal husbandry, mining, road, dams and building construction. They may relate to health and sanitation issues. They may pertain to ownership and tenure issues. These may involve questions of social and economic status, gender and other equity issues. They may relate to customary and formal legal regimes. They may address themes relating to management and development of natural resources.

Consider, as an example, the use of groundwater in coastal tracts of Uttara Kannada district of Karnataka. Traditionally, the crops of this region include rice, largely cultivated by small-holders, and betel nut, primarily cultivated by richer orchard owners. When, 50 years ago, there were no electrified pump-sets, the water table was at a depth of about five metres, and the small-holders were able to hand irrigate and raise a second crop of rice in winter. Following rural electrification, free power was made available to farmers along with subsidised pump-sets. These facilities were primarily availed of by the orchard owners, who began to extensively irrigate betel nut in the dry season, substantially increasing its yields. This drove the water table down; as a result the smallholders could no longer raise a second rice crop. This has compelled their women to switch to sale of fuel wood as a livelihood activity in the dry season, resulting in a rapid pace of forest degradation and conflicts with forest authorities. Surely, a rich variety of student projects infused into various subjects could be designed around such a context.

ICT Tools

The tools of modern information and communication technologies (ICT) are now reaching out to larger and larger numbers of people, even in relatively remote rural areas. In Karnataka a programme called 'Mahiti Sindhu' has provided good computer facilities, including access to the internet, and training in computer usage, to a large fraction of government schools. Panchayat offices too are being provided computer facilities in many parts of the country. Private enterprises have stepped in to set up programmes such as E-choupal of ITC that is permitting access to computers, internet and web-based information on prices and markets for agricultural produce in many villages in several states. Cellular telephones are becoming widely available and can now access the internet. M S Swaminathan Research Foudation is spearheading the drive to make "every village a knowledge centre" that aims to reach some 5 lakh villages by 2007.

Today these tools are primarily being used for routine applications and for a top-down flow of information. Thus, while in the Mahiti Sindhu schools the students learn the use of Microsoft packages, they have little opportunity to undertake creative applications on their own. In many schools and colleges students surf the web to help them in carrying out environmental education projects. But all they seem to do is to download mostly irrelevant information from US websites. There is practically no information on environmental issues of relevance to us in India on any of our websites. Moreover, there is very little available in Indian languages. Here then is a tremendous opportunity to create valuable knowledge resources pertinent to good management of our natural resources by leveraging the information with official agencies, the information that may be generated through PBR, through student projects, and through scientific research programmes. These resources could then be made available as transparent, publicly accessible databases on the web. These exercises could engage our youth, our barefoot ecologists in creative activities. They could help them become a part of a countrywide knowledge network with flows of information, not just from top to bottom, but bottom up and horizontally as well.

Scientific Exercises

Using the data on transparent, and publicly accessible websites developed, at least in part, on the basis of school exercises, it would be easily possible to undertake a number of scientific exercises based on the comparative method applicable to the study of complex systems. Thus, one may visualise on such a website, countrywide spatial data on soil and rock types, rainfall, cropping patterns, and human population density, along with that on the depth of the groundwater. Students could access such data and undertake statistical analyses of different levels of sophistication to assess the influence of various factors on the depth of underground water table. They may then be introduced to the world of hydrological models and try to understand the underlying processes.

Right to Information

The most serious lacuna in our approach to managing information on India's natural resources has been a lack of openness and willingness to take everybody along. The inclusive, open approach advocated here depends crucially on free access to all information, except where very evident security concerns are involved, to all people. Today, this would be best ensured by posting all pertinent information on the web, in English, as well as in all Indian languages. The recent legislative provisions towards ensuring freedom of information have fortunately removed many bureaucratic hurdles to such an endeavour. It would be most useful at this juncture to organise "Information Clearing Houses" to help people access and then widely share the information accessed under this act. One component of such Information Clearing Houses should be an Environmental Information Clearing House that would systematically bring into public domain information such as all statistics being maintained by various pollution control authorities, detailed project reports of development projects such as dams and highways, all commissioned environmental impact assessments, as also forest working plans and protected areas management plans. The Environmental Information Clearing House should also have links to the pertinent satellite imagery and maps, resource maps, along with all properly validated information collected through the PBR, and through environmental projects undertaken by students, scientific publications and any other pertinent information. All this information should be made available in a highly disaggregated form, in its full details so that it can be effectively scrutinised and improved upon.

Share and Inform

It is only when we successfully institute such a "share and inform" approach in place of the current "control and command" approach, that we would be able to do justice to India's rich legacy of folk and classical knowledge, its extensive scientific and technical capabilities, its enormous human resource in the form of young students, and our vital heritage of natural resources. EPW

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