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ENVIRONMETRICS:
Objectives and Strategies

by

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Key-note Address: Conference ENVIRONMETRICS
Cairo, Egypt, April 4 to 7, 1989

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Burlington, February 1989

ENVMTR89

1.- Introduction

The purpose of this conference has been defined: To promote the development and application of statistical methods in environmental assessment, and to devise a mechanism for maintaining regular contacts among statisticians and environmental scientists.

I think, this definition is a very happy one: It casts not only a bridge between two scientific fields, STATISTICS and ENVIRONMENTAL SCIENCES, rather, it recognizes this linkage as crucial. Most of us working on environmental issues, at one time or another, have used statistical techniques for analyzing data and ventured into making inferences. However, the understanding of statistics for most of us is "second-hand", i.e. learned from textbooks. This limits our ability to use statistics correctly: Indeed, rather than correct, incorrect use, even misuse is often the rule, making statistics a questionable paraphernalia.

There is also the counter-fact: Statisticians, though highly qualified in their field, cannot develop and correctly apply their science without understanding the properties and functions of the natural environment. Insight into, and proper appreciation of the dynamics of natural systems, as well as familiarity with the methods of analysis, are prerequisites for the correct development and application of new statistical concepts. Otherwise, statistical inferences - though mathematically correct - are deemed to be arbitrary, and to the natural scientist unintelligible. Also this we have seen happening.

What connects both fields, of course, is data. The methodological aspects regarding the technological means of data acquisition, though of paramount importance, are outside the scope of this conference. Yet, exploration of the rationales for which data are collected in the first place, is part of the central theme. This should lead into considerations about OBJECTIVES and ways and means of DEVELOPING STRATEGIES which may range from perceived needs for efficient sampling designs on one end, to the development of complex strategies aimed at effectively controlling specific environmental problems, on the other.

My talk will focus on aspects and topics of general nature rather then on specifics. I will ask myself a number of questions and explore some related avenues which, I think, are fundamental to make rationalization and consolidation of the linkages between different facets of science possible. Mainly, I think that prior to venture into discussions about common technological terminologies, it is necessary to define the platform on which such undertaking is to be grounded.

2.- The realm of environmental sciences

The first question I wish to explore is that:

WHAT IS MEANT by the term "ENVIRONMENT" ?

Obviously, from the answer to it depends what Environmental Sciences should be concerned about. The lexicographic circumscription of the term "Environment" lists a number of items, two of which are relevant to our theme:

In Funk & Wagnalls Standard Dictionary "Environment" is defined as,
a) the aggregate of all external and internal conditions affecting the existence, growth and welfare of organisms;

b) one's surroundings or external circumstances collectively and/or individually.

This definition immediately shows the complexity and range of the subject in question. Under heading a) the focus and concerns are all-encompassing-global, under b) specific-local. However, the two categories are neither opposites nor mutually exclusive but merely represent the boundaries of the field in which the actual reality is embedded. Moreover, one can also argue that, philosophically speaking, the term 'environment' is a misnomer in respect to the fact that environment is not external to man, but man-inclusive. Implicitly, the given definition makes this point, though its reality derives from the actuality of the ever increasing world-wide pollution, rather then from classical Ontology.

Seen in this perspective, then, the domain of the science concerned with the environment, characteristically enunciated as a plural, i.e.

" ENVIRONMENTAL SCIENCES "

should encompass everything being in the reach of knowledge. This, of course, is impossible, but the principle and its implications are worth considering.

In terms of an operational science, the realm of Environmental Sciences needs be narrowed down. Nontheless, given the basic premise, the problem is not easy to overcome. Indeed, any attempt to enunciate a definition of the term 'Environmental Sciences" which is both, succinct and at the same time sufficiently broad to satisfy a large audience seems almost impossible. This becomes evident if one considers the array academic disciplines quite normally involved in envirnmental studies; cf. Table 1.

TABLE 1

Table 1:

ENVIRONMENTAL SCIENCES

A complex not well defined issue!

Some components:

ATMOSPHERIC & EARTH SCIENCES:

OCEANOGRAPHY <-> METEOROLOGY <-> HYDROLOGY <-> GEOCHEMISTRY-> EDAPHOLOGY

Other Disciplines involved:
Physics - Chemistry - Biology

PHYSICAL & PHYSIOLOGICAL CHEMISTRY <-> TOXICOLOGY <-> ECOLOGY

GEOGRAPHY & ANTHROPOLOGICAL SCIENCES

STATISTICS & MATHEMATICAL MODELLING

Driving Forces:

ECONOMY:
Agriculture - Industrialization - Urbanization

Hence:

AGRONOMY <-> INDUSTRIAL TECHNOLOGY <-> SOCIO-ECONOMICS

MEDICINE <-> PHARMACOLOGY <-> PSYCHOLOGY

Accordingly:

An all encompssing definition of the realm of ENVIRONMENTAL SCIENCES ought to cover an array of potential topics ranging from the natural environment external to - though affected by - man, to his working and living environment directly including man.

The listing given is far from being complete, and does not even mention such important sciences as Medicine, Pharmacology, Toxicology, Psychology, a.o., all of which share some common grounds with environmental sciences.

Moreover, the problem is compounded by the fact that the academically defined disciplines in their practical application cannot be divorced from those human activities which are the driving forces for and underlying the environmental problematics of our days, i.e. the economics and their related subcomponents such as agriculture, industrialization, urbanization. Isolation of an academic activity, called "Environmental Sciences", from these sectors would indeed be meaningless. Together, this puts a heavy burden on the environmental scientest who, on one side, has to be technically competent in at least one specific disciplinary field, on the other, has to remain open-minded flexible, be prepared to live within a context of uncertainties. That this is often detrimental to the development of sound integrated strategies for solving environmental problems, is obvious, ignoring with this token all other impediments such as political, legal and administrative limitations.

4.- Some conceptual issues

In a more restricted sense, remaining within the realm of science, there are other challanges, however, which not only need be considered but need be explored within the broadest context possible. The field of environmental sciences is still young compared with other disciplines, and as a consequence the development of a consistant conceptual framework is still in its infancy. This becomes evident when one tries to integrate fields of essentially different nature as e.g. is the purpose of the present conference.

The recurrent question: "Why do we collect data and do statistical analyses?" posed in this way, is, trivial, but nevertheless needs be answered by each environmental sector in relation to its own specific objectives. This will be done during this conference in various technical sessions. Therefore, I do not pursue this matter to any degree. Rather, I wish to rephrase the question in a more conceptual sense, asking:

"WHAT ARE THE CONCEPTUAL ISSUES
WHEN GATHERING INFORMATION
- whatever the immediate aim may be ?"

This leads to a number of sub-questions the first of which being:

"WHAT ARE CHARACTERISTIC DIFFICULTIES IN ENVIRONMENTAL STUDIES ?"

Clearly, several different subjects may be listed as possible answers. Also, non of these may be specific to environmental studies but some will recur more frequently as a source of problem.

Among these, perhaps one of the most obvious is that of

TIME-SPACE HETEROGENEITY.

Time-space heterogeneity often creating difficulties in actual data and information gathering not easy to overcome is a characteristic property of the structure of the environment. It is true that certain phenomena can be isolated from their intrinsic time-space subjugation by studying them under apprpropriate lab conditions. For many purposes such experimental artifice are indispensable but lab conditions never reflect the real world. In the real world, phenomena are unique, i.e. non repetitive. It is not possible to repeat measuring the temperature which occurred at time 3 p.m. 10 years ago in the locality situated at Lat. 27°, Long. 55°, at 2500 m Altitude. If that information was not gather at that time and that locality, there is no information at all.

Yet, certain environmental phenomena are more orderly structured in time and space than others. Phenomena of the first kind are not as hopeless, even when specific information is not available. If e.g. temporal previous and after measurements or spatial measurements at neighboring locations are available, one can still make reasonable estimates about what the temperature must have been at the specified time and place, using appropriate interpolation techniques. In other words, such phenomena are reasonably predictable.

Conversely, phenomena of the second kind are much more difficult to handle depending on the relative mixture of predictable and chaotic events. As a consequence, in order to characterize such phenomena appropriately, the number of measurements in time and space must be commensurate to the level of non-predictable elements.

The point I am heading to is this: Given the impossibility of measuring everything at every place and time - one of the most

CRUCIAL PRINCIPLES
to be observed in
DESIGNING AN ENVIRONMENTAL INFORMATION SYSTEM
is to properly
ACCOUNT FOR THE EXPECTED TIME-SPACE HETEROGENEITY

In fields with a long tradition in such matters, as e.g. in meteorology and their sub-branches, this postulate is well incorporated into their information systems. In other sectors of environmental studies there is still a long way to be gone.

This is one fruitful area for close cooperation between environmental scientists and statisticians. The problem to be solved is that of <u>optimizing</u>

the time-space resolution within the logistic constrains given. Concomitant minimization of the logistics required and maximization of the information return to be expected will not only lead to more coherent data, but will in the end have its payoff also in money.

To provide an example out of my own competence: In designing a survey and surveillance program in the adriatic sea a combination between a monthly grid point data collection and a daily one-station collection was adopted. The former was designed to arrive at a sufficient spatial resolution, sacrificing on time resolution, and the second was designed with the opposite objective in mind. With these programs running parallel over several years it was possible to get insight into complementary aspects of the phenomenology of coastal eutrophication which otherwise within the logistic constrains would not have been the case.

From such and related considerations follows the postulate that environmental measurements serve the purpose only if they include

a) THE CRUCIAL ITEMS
taken
b) AT THE CRUCIAL LOCATION
c) AT THE CRUCIAL TIME

This leads over to the question about the crucial items which we haven't considered yet. It is clear that what has to be defined as CRUCIAL ITEM or CRUCIAL MEASUREMENT has to come out from the particular question or questions asked by the researcher. Hence, no general answer can be given. Nevertheless some considerations of principle nature can be useful. Foremost it is to be noted that measurements are meaningless unless they can be related to something within the frame of our pre-knowledge about the system in question. Exception to this postulate are measurements which are declared as exploratory. But even in such cases one will find that scientists usually initiate exploratory measurements on grounds of some kind of pre-knowledge, or some kind of hypothesis.

Unfortunately, it must be remarked that - despite of such warnings - some routine programs are carried out, or continue to be carried on with but little pertinence to anything. Even certain of the internationally launched routine programs must be denounced to be wanting in this regard. Data gatherings of this type have but little to do with science; they become, in the best, data catalogues, in the worst, pseudo-scientific journalism.*)

*) (P.S. I wish to make here the distinction between objective-oriented and curiosity-oriented studies. What is said above applies to the former, not necessarly to the latter. Without curiosity-oriented explorations no progress in science would be made).

Therefore, we have to ask ourselves:

"WHAT DISTINGUISHES SCIENCE
(and in our context Environmental Sciences)
from DATA-CATALOGS and PSEUDO-SCIENTIFIC JOURNALISM ?"

The answer is:

A MODEL CONCEPTION

With the term 'model' I do not necessarily imply a mathematical model, though in many cases it will be. With 'model' I mean in the first place an organized way of thinking about, and approaching a subject matter. In this sense, a model can be a holon, a flow diagram or a Gauss' error function. The only difference between this examples is that they occupy different levels within the hierarchy of thinking modes.

In a more mathematical sense, though not exclusively, models have to satisfy certain essential criteria, namely

MODEL CRITERIA:
GENERALITY - REALISM - PRECISION

The relationship between these elements represents, to say, the boons of a much wider conception which embraces the whole field of scientific endeavors:

CONCEPTS - THEORIES - OBSERVATIONS

This thinking pattern is typical for unfettered research and as such is not only of general applicability, but is indeed enormously powerful. Much of our advances in modern science is the result of the consistent application of this scheme as an organizer.

Environmental sciences are only partially unfettered. Most of the studies done in environmental sciences originate, or are motivated by

A PERCEIVED PROBLEM WHICH NEEDS SOLVING.

Therefore, research application becomes an integral part of environmental studies. The presence of this element is both, a strength and a weakness. This latter is, at least in part, responsible for what I mentioned previously in regard to tendencies toward simplicistic data collection. Conversely, the strength of research application lies in the fact that something has to be solved in the first place, but also in the fact that because of such constrains one often discovers which part and/or what process of a system are least understood and require more appropriate studies.

This forces us once more to reflect on how best to interrelate and conceptualize activities in environmental sciences. The typical elements one finds within this context are:

MONITORING - DATA INTERPRETATION - RESEARCH

These elements too are bonded within a circle, yet, the center of reference is not that of 'UNDERSTANDING' but one that implies ACTION. In other words, the three categories of activities form the elements for developing

STRATEGIES OF CONTROL & CONTROL TECHNOLOGIES

The function of research, of course, is, and remains, that of UNDERSTANDING. Without understanding of how the system is structured and working, data interpretation is not possible. However, also monitoring, i.e. the activity of data collection must be guided by research.

MONITORING CANNOT BE DIVORCED FROM RESEARCH
AND DATA INTERPRETATION

Yet, this is not a one-way street: Also research profits from the other activities, in particular data interpretation. Data interpretation may lead to new insights into the system, but also will reveal real gaps in our understanding.

It is clear that the interconnection between these three fields of activity offers the most fruitful ground for close interaction and cooperation between the environmental scientist and the statistician. While in the past, and still often today, the main reliance for providing the elements necessary to develop control strategies rested with the natural scientist or its close alleys, in a more advanced environment of research application the statisticians must now play an equal role. Indeed, it would no longer be defendable to ignore its essential contribution.

5.- **Further pursuits**

Let me pursue this questions a little further. I mentioned that in relation to the items to be measured, it is important to measure the crucial items at the crucial location and at the crucial time. In any practical situation this leads immediately into the question about the

SCOPE & DIMENSION OF THE TASK

Is the scope local, regional, global; is the task specific, i.e. unimodal, or more dimensional; is the system well defined, i.e. has it well recognizable boundaries, or are the boundaries diffused; is the system a sub-system of another system which co-determines the characteristics of the sub-system, or is the system more or less self-contained, etc.? Other questions in this vain are: What is the dependency of the variables between themselves; which one of the variables can be sacrificed first, if necessary; are there hidden variables which may distort the measurement of the variables selected; how frequently does one have to measure, both in space and time, to meet all the conditions, etc.? And not least: Are there other information bases available which should be consulted prior to embark into a costly study program; particularly , what can be learned in advance from such sources about the system, and/or even from sources which appear to be only marginal to the task ?

To this later point I can just give an example out of my own experience: Some years ago I was called into a country to advise on their monitor program regarding an important tropical lake. I had two weeks. The first week I capsuled myself into a room, asking about whatever information I could get about the basin, including climatological, pedological, land use maps, vegetation maps, etc. Toward the end of the week, the study director became a little uneasy that I was not particularly interested in their monitoring program; the following week, when we finally went down to business, he was surprised about all what I knew about the lake prior to have whether seen it, nor looked on specific data.

By the way, I learned this technique in quite a different way here in Egypt when I was a young and not yet too experienced consultant. At that time, a new fisheries expert was sent by FAO who should have advised on Egyptian inland fisheries; yet, he didn't have any knowledge about the Egyptian fish fauna. For a number of weeks he closed himself into his lab, asking only that each day he would receive a number of fish specimens which he diligently dissected according to classical techniques. The same uneasiness developed about him. Yet, after he finally resurrected from his retreat, he astonished everyone as to his knowledge about habitats, food sources, spawning grounds etc. of each species without ever having consulted one book. I, myself, had learned from that man in a few weeks more than I ever had at university.

This example may lie somewhat outside the conference theme; yet, it demonstrate in a unique manner that:

KNOW YOUR SYSTEM !
and
KNOW HOW TO DEAL WITH YOUR SYSTEM !
are the most important imperatives in scientific endeavors.

There are many techniques and approaches possible to come to term with these imperatives, of course; yet, it is not merely a question of learning the textbook. It is rather a question of methodology, i.e. of mental orientation and organization, as I already pointed out.

In regard to research and project design one of the recurring dilemmas one is always confronted with is the question about how much effort should be put into

SINGLE CASE - intensive <u>versus</u> MULTIPLE CASE - extensive

studies. Of course, this dilemma arises most often from the limitations imposed by logistic and/or economic constrains, but at times also because of general uncertainties about the subject, and the state of the arts.

Ideally speaking, one would like to study as many single cases to any depth possible. The more cases are understood in-depth, the more can one be confident into validity and generality of the inferences drawn from the studies. Illustrating this idea with the aid of a conceptual diagram (cf. Figure ____) the cumulative information resulting from such broadly conceived studies would line up relative to both, the single case and the multi-case axes symmetrically along the mean divider, and the information would become fully exchangeable in either direction. In other words, the RISK TO BE WRONG, or the level of UNCERTAINTY in regard to to both, the single and the multi-case would decrease proportional with the number of cases dissected.

Under actual conditions, this ideal situation can rarely be realized. Depending on the question and the constrains imposed, studies are either more single case-intensive, or more multi-case-extensive oriented. This means, the cumulative information is not symmetrically distributed, and unqualified exchange between the single and multi-case is not warranted. In other words, inferences from the single to the multi-case, and vice versa, is affected with a higher level of uncertainty. This fact is often ignored.

However, one has also to be aware of the fact that either approach, intensive single-case, and extensive-multi-case study, at a certain point leads to a plateau of the information return regardless of the amount of effort put into the study. This means that the

RELATIVE INFORMATION GAIN PER UNIT OF EFFORT

tends to decrease progressively over the lifetime of the study. This is illustrated with Figure _____.

(RELATIVE INFORMATION RETURN DIAGRAM)

The implication from this for research management is that scientists and research managers should remain allert to the occurrence of the onset of the plateau - what further implies that when this situation arises a decision must be made as to how far the study should be continued, or be channeled into another direction.

A next level in this endeavor regards the pursuit of integration of the acquired knowledge into a consistent model or theory, i.e. the pursuit of generalization. Lucky intuition is often called for - and that may be true - but also in this case an organized methodological thinking pattern can be helpful. This can be thought of as a combination of four elementary component approaches, i.e. as the combination of four elements in groups of two. The four elements being the mentioned:

SINGLE CASE versus MULTI-CASE
combined with the categories of
ANALYTICAL versus HOLISTIC.

The way over which integration and generalization is achieved, is twofold, proceeding from the analytical single-case over holistic model conception to the multi-case stage, or over a comparative multi-case analytical stage to a holistic conception. These ways are not mutually exclusive, they are complementary. Clearly, the direct progression from the single-case to the general case is not possible; conversely, any new single-case which does not fit the assumed general case indicates that the generalization is not valid, and the process has to be restarted from square one.

The underlying concept can easily be broaden further by superimposing over the scheme shown a second level which makes it three-dimensional, etc. Elements or compartments which appear at higher levels would include items which transgress simple scientific matters, such as applicability in general, technological and economical constrains, societal acceptability, moral dimensions, a.s.o.

This leads over to the question of the

ROLE OF SCIENCE
and in particular applied sciences
WITHIN THE SOCIAL FABRIC

What we are discussing to-day, is indeed science in its relation to management of the environment, and in this regard, the contribution of science, and its role must be evaluated within a broader context. Environmental Sciences cannot remain isolated from its social surroundings, but also the social surroundings, to-day, cannot remain disconnected from science. In other words, the one cannot fulfill its function without the other. This connects the two spheres of activity intimately. The correct interaction between the two can be visualized as a cyclic input-output process which relates

USER OBJECTIVES - PROBLEM AREAS - SCIENTIFIC KNOWLEDGE -
MANAGEMENT
on on hand, with
SOCIAL OBJECTIVES - PUBLIC AWARENESS - RESEARCH FUNDING - CONTROL
TECHNOLOGY

on the other hand. In their totality and interconnections, these elements are the building blocks necessary for developing coherent

ALL-ENCOMPASSING STRATEGIES FOR MANAGING THE ENVIRONMENT
within a
SOCIAL CONTEXT

What is expressed here, is the fact that each sphere has its responsibility, yet, not unconnected, but in mutual symbiosis with and including all facets of society. In other words, the responsibility lies with both, the scientific community and the movers of society, i.e. politicians, the economic sectors, and the public educators at large.

6.- Some examples

Let's now look on some examples. Obviously, they are picked out of my own fields of competence, i.e. the water sector. I mentioned previously the need of conceptual organization of the specific subject matter. First, let's look on some of the characteristic problems as they emerge along the line. I have chosen here problems typical in water supply reservoirs:

PROBLEMS IN WATER SUPPLY RESERVOIRS

The problems listed are:

WATER QUALITY IMPAIRMENT
RECREATIONAL IMPAIRMENT
FISHERIES IMPAIRMENT
AGING

Also others can be mentioned, such as siltation, impairment of navigation, salinization, a.o.

Combined wit this listing is a listing of causative factors, such as eutrophication, toxic substances, acid rain, dissolved and suspended solids, etc.

Such a tabulation - which, by the way, is not complete - represents the first level of ordering. Governmental agencies which have to deal with such problems, typically work at this level. This is due to the many problems which needs solving quickly, often in a brush fire fighting kind of situation. Clearly, this often leads to a chopping of efforts, and inconsistency of knowledge accumulation.

At a long run, the prevalence of this approach cannot be satisfactory. Hence, it becomes necessary to develop more integrated conceptions. E.g. one will recognize that certain problem areas - though characteristic in their main manifestations are interconnected, i.e. not entirely disconnected. Thus, eutrophication, acidification and pollution by toxic substances are not clearly separate:

THE POLLUTION TETRAHEDRON

Thus, lake acidification is not necessarily only caused by acid rain, but can also be caused by certain industrial discharges, or acid mining, to give an example.

Another level of integration starts from the basin itself, and this not in specific terms of problems, but by depicting a general model which connects all the principle causative factors which determine the properties and potential reactions of a embedded water body within in a hierarchical context:.

BASIN MODEL

For any specific purpose such a model can then be adapted to the particular situation and objective of the study. The importance of this approach lies in the fact that the problem which calls for a study in the first place, shows up in the context of a wider nexus, and not as something outside of it.

I could proceed further in this vain; yet, in order to round up the though along this line I show a last example on which I am just working, and which shows how such general thoughts are adapted to a specific problem and situation. It gives also a possibility to elucidate the role the statistician can play in solving such a problem.

The example refers to a coastal area in Italy highly eutrophied which calls for a control of nutrients originating from sources located in its hinterland. A ten year study program has shown that phosphorus is the first factor which has to be brought under control. Accordingly, phosphorus is the critical item to be measured. For this reason a phosphorus budget for that region has been attempted which is summarized in the form of an

INPUT-OUTPUT and DISTRIBUTION FLOW DIAGRAM
or
PHOSPHORUS BUDGET

The background material used for this diagram is very complex covering a wide variety of single items and estimates. This is of secondary importance for the present purpose. The basic structure of the flow diagram is an adapted version of the general flow diagram presented previously. What one wishes to understand in this case is:

a) the TOTAL INPUT of phosphorus into the region;
b) the distribution and FLOW PATTERN through the region, including internal RECYCLING paths;
c) the TOTAL EXPORT of phosphorus from the region, with special attention to the output into waterways.

The final outcome of this analysis should show:

a) which ones are the CRITICAL PATHWAYS;
b) which of these are CONTROLLABLE;
c) HOW MUCH can be brought under control;
d) what would this mean in terms of PROBABILITY OF REDUCING eutrophication;
e) what are the SOCIO-ECONOMIC IMPLICATIONS deriving from this.

This latter embraces a whole array of things which are outside the present interest. However, what is of immediate interest, is e.g. the fact that:

a) many QUESTION-MARKS remain unsolved;
b) the structure is a network of which each compartment and path has its own UNCERTAINTY;
c) the effect of manipulating on part of the system on the BEHAVIOR OF THE TOTAL REMAINS UNCLEAR.

The statistician comes in here in many, almost all parts of the analysis. First of all, many information is already existing in the usual statistical state archives. However, there are also items which are not, but which result as being crucial. Then the statistician comes in a straight forward way in evaluating source and flow estimates. However, where he - as professional plays the most important role, and of which we have not yet taken full advantage, is in the evaluation of the combined network effect and the evaluation of the propagation of the uncertainties within the network. This leads directly into the question of RISK - however we wish to define this term -, namely in the sense what I specified above under c).

We have approached this question up to now at the end of the chain, i.e. considering the

PROBABILITY OF BIOMASS OCCURRENCE
AS FUNCTION OF THE PHOSPHORUS IN THE SEA.

This comes out from all the data collected during a 10 year monitoring program. Using common statistical techniques, Gumbel theory and Monte Carlo simulation, we are able to assess the probability of the occurrence of algal blooms at different levels of phosphorus present. Yet, the link to load, i.e.

the hinterland, is not yet established from the point of view discussed above.

YET, FOR CORRECT MANAGEMENT THIS IS CRUCIAL !

7.- Concluding remarks

I realize that I have not been particularly specific. Also, I have touched only on a few selected aspects. This was intentional. I felt it to be more important to speak to some general matters which are common to all of us present at this conference. The scientific literature is full of individual case studies; in addition, most of us are normally involved in such studies. However, at times, it is also necessary to stay back, and to consider matters from a broader perspective. This shows where in our approaches and conceptions we are strong, and where we are still weak and need some further exploration.

ENVIRONMENT

Definition complex:
<u>all-encompassing-global</u> to <u>specific-local</u>

1.- The aggregate of all external an internal conditions affecting the existence, growth and welfare of organisms;

2.- One's surroundings or external circumstances collectively and/or individually.

But:

MANKIND, as a biological species, is
PART OF ITS NATURAL ENVIRONMENT AND OF ITS OWN ENVIRONMENT
i.e.
MAN DEPENDS, CREATES & CHANGES THE ENVIRONMENT
HE IS NOT "EXTERNAL" TO IT!

In its endeavors, man as a species has become a global force,
though, as an individual,
he may remain captured in his own local surroundings.

ENVIRONMENTAL SCIENCES

A complex and not well defined matter!

Some components:

METEOROLOGY <-> HYDROLOGY <-> EDAPHOLOGY <-> GEOLOGY

other PHYSICAL SCIENCES <-> CHEMISTRY <-> BIOLOGY

GEOGRAPHY

AGRONOMY <-> SOCIOLOGY <-> INDUSTRIAL TECHNOLOGY

Driving forces:

ECONOMICS

Agriculture - Urbanization - Industrialization

Hence:

An all encompassing definition of what one may list under the notion of ENVIRONMENTAL SCIENCES ought to cover an array of topics ranging from the natural environment external to, though affected by man, to his working and living environment directly including man.

Some Conceptual Issues

WHAT ARE THE CONCEPTUALLY IMPORTANT ISSUES ONE HAS TO KEEP IN MIND WHEN GATHERING INFORMATION ?

- whatever the immediate scope may be -

or,

WHAT ARE THE PARTICULAR DIFFICULTIES IN ENVIRONMENTAL STUDIES ?

CRUCIAL PRINCIPLE

to be observed in

DESIGNING AN ENVIRONMENTAL INFORMATION SYSTEM

is to properly

ACCOUNT FOR THE EXPECTED SPACE-TIME HETEROGENEITY

Hence, measure:

THE CRUCIAL ITEM(S)
AT THE CRUCIAL TIME
AT THE CRUCIAL LOCATION

WHAT DISTINGUISHES SCIENCE

(and in our context Environmental Sciences)
from

DATA CATALOGUES and/or **PSEUDO-SCIENTIFIC JOURNALISM ?**

Answer:

A MODEL CONCEPTION !

MODEL CRITERIA:

GENERALITY <==> REALISM <==> PRECISION

CHARACTERISTICS OF UNFETTERED RESEARCH:

CONCEPTS <==> THEORIES <==> OBSERVATIONS

WHAT DISTINGUISHES APPLIED FROM UNFETTERED RESEARCH ?

Answer:

**A PROBLEM PERCEIVED BY SOCIETY
WHICH NEEDS SOLVING !**

Main Elements of Approach:

MONITORING <==> DATA INTERPRETATION <==> RESEARCH

leading to:

CONTROL STRATEGIES and CONTROL TECHNOLOGIES

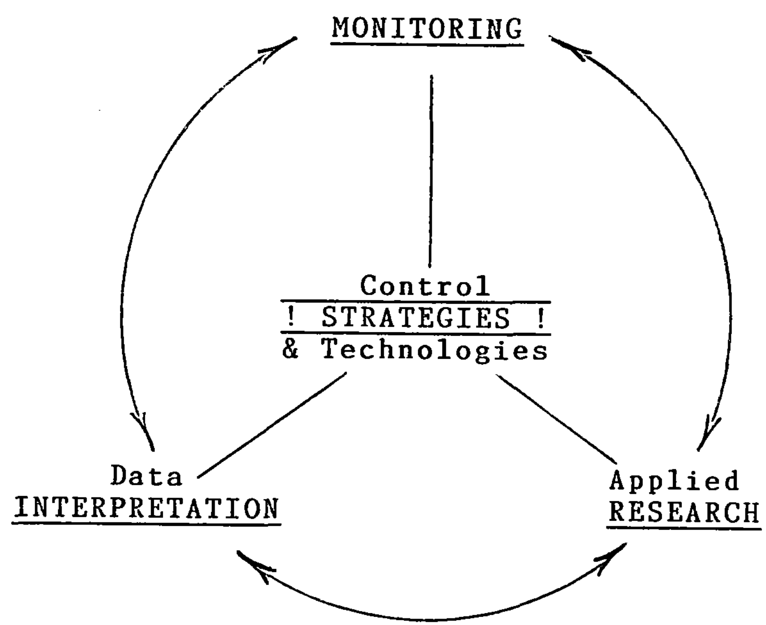
But:

MONITORING and DATA INTERPRETATION

- under no circumstances -

CANNOT or MUST NOT BE DIVORCED FROM RESEARCH !

Conceptual Model of Applied Sciences
and Research Application:



KNOW YOUR SYSTEM !

and

KNOW HOW TO DEAL WITH YOUR SYSTEM !

Approaches of Analysis:

SINGLE CASE - intensive versus **MULTIPLE CASE** - extensive

But:

BEWARE OF DIMINISHING INFORMATION GAIN !

Approaches of Integration:

SINGLE CASE versus **MULTIPLE CASE**

combined with

ANALYTICAL versus **HOLISTIC**