HUMAN IMPACT ON TRANSPORTATION AND DIVERSITY IN ECOSYSTEMS. HOW FAR IS EXTRAPOLATION VALID

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Interaction between man and the rest of the biosphere may be discussed conveniently in a number of separate items:

1. Exploitation.- To take something out of an ecosystem means a relative reduction of the ecosystems biomass, and, if productivity is not negatively affected, an automatic increase of turnover. Turnover is much increased by conscious management for a high yield. It can be said that selection is no more in the "interest of the ecosystem", but in the "interest of the exploiter", that is, man. Selection for prolificity is encouraged, and r-selection spreads across many layers of the ecosystem.

Exploitation has been made easier in areas subjected to a fluctuating climate, where simple persistence requires that ecosystems overshot some limit of primary production. It is a security system that leaves, more often than not, a surplus to go down a detritic and inefficient path, or else to be used by some outsider (man). Moreover, diaspores and ressilient stages apt to resist the inclement season could provide an acceptable food for man. The situation is characterized further by a periodic or persistent accumulation of nutrients in soil, and a high ratio production/biomass, with noticeable bursts of productivity. Weeds become exploitable and exploited crops; tendance to monoculture has been unconscious and, only later, purposeful.

Fluctuating ecosystems, in a given instant of time, have a lower diversity than ecosystems that remain more alike during the year over, and the result of exploitation is a further decrease in the diversity of communities.

In tropical zones, only the high lands and the areas subjected to periodical flooding (rice) could raise important crops.

Exploited animals should be at the end of rather short food chains. This is one of the reasons for the low exploitability of oceans. Only the sensible use of the behaviour of the same animals allows to make important catches; nevertheless, oceans provide only 1% of food of mankind. The richer areas in the sea are the upwelling regions subjected to constant or periodic enrichment, and to important fluctuations of populations. Ecologically they can be compared to the grasslands where agriculture was started.

2. Transportation.- There are three main stages in the use of nature by man. The key factor for moving from one to the next has been transportation, and the result has been increased crowding. This is not always negative, because it has been the source of our culture.

In a first -or paleolithic- stage, we have local exploitation, local feedback and a density that compares with the one attained by primate populations (o.3 to 1.4 individuals per square km).

Nomadism is a way to escape local feedback: exploit -and ruin- one area, go to the next, and so on. In agriculture supported human populations, density increases by two orders of magnitude.

The same result as moving back and forth people and animals can be obtained moving goods. Fields can be fertilized and watered and foodstuff supplied to large urban populations. On a world basis, and in present times, only 12 % of total energy degraded directly by man goes through the biological or endosomatic metabolism; the rest is cultural or exosomatic metabolism and a major part of it is used in the different forms of transportation. Transportation has also biogeographic implications: cultivated stocks, pests, germs, have been shifted by man. By the way, essential inequality of exosomatic metabolism, among humans and human groups, as compared with endosomatic metabolism, where variance is much less (death sets soon a limit), is the source of most political and social problems (Margalef, 1973a).

Pollution is related to transportation. Pollution is the result of one way and converging transportation. As a consequence, pollution acts as a buffer or a brake, slowing down natural cycles. Doubling the energy put in transportation could whip off the problems of pollution, closing and speeding up the cycles, but are we prepared for such an acceleration?

Transportation magnifies the impact of man as an exploiter. Transportation is less subjected to feedback regulation than nomadism is, and leads from local to global feedback. This could be modelled along the following lines: Consider a number of relatively independent small models, and in each of them a local human population in interaction with a local ecosystem.

Connections between the different blocks is feeble, each one has a homeostatic behaviour, and all are embedded in a biosphere, which state is not actually endangered by some extreme state in one of the blocks. Transportation means a stronger lateral coupling of the partial models, more in the part of the human level than in the rest. Man becomes apt to destabilize the system on a global area, and the systems cannot more be closed -or modelled- over a restricted area.

Development of natural ecosystems, along succession, leads to a development of a vertical system of transport, and, at the same time, to a regulation of the horizontal transport, that is kept to a minimum. Such reorganization of the path followed by the elements in the material cycle of the ecosystem seems quite general. The forest provides excellent examples, as well as the central areas of the oceans. It should be added, perhaps, that limitation of horizontal transport has not to be understood as an actual minimization of transported matter, but rather as a trend towards making symmetrical any transportation over an horizontal plane.

The impact of man over nature is a tremendous increase of horizontal transport, in all forms: erosion, pollution, concentration of produce in towns and along highways, etc.

3. Organic pollution.- Organic matter is concentrated, half used and dumped in small areas, carried on along converging paths. Pollution, thus, is a link between separate systems, and, in one of them, at least, creates a condition of stress. Stress is used here to describe a rather inefficient use of resources, that results in the separation of some nutrients out of the cycle, at least temporarily. This is a positive brake (see later), much more important that any feedback of esthetic or economical kind, the only present in the popular views about pollution. As well as upwelling and eutrophic systems, pollution is characterized by a high production/biomass ratio, and by communities of low diversity.

Diversity is low, either because "hard" conditions limit the number of species to a few resistant ones, or because fluctuations and irregular accelerations favour a small number of species, rather free of links with others and characterized by a high rate of multiplication. In recent times it is becoming popular to use as an index of pollution, any depression of diversity values below the initial or usual values.

4. Chemical pollution.- Introduction of molecules designed to interfere with vital activities of other species is a strategy for competition already in use by prehuman organisms, as low as red tide organisms may be. The input of unusual organic compounds and of elements in unusual concentrations have a variety of consequences, but at the ecosystem level, the results are often comparable. In general, pesticides lower the diversity of the communities, in part because species with a low rate of multiplication may be more affected than the true pests. In the distribution of pesticides and toxic elements through the parts of the body, and through the parts of the ecosystem, concentration becomes inversely related to turnover. It increases more in the higher trophic levels and, in consequence, mortality is expected to be increased in the same levels, adding another cause for a drop in diversity and for an increase of the ratio production/biomass. As a non negligible impact of man on evolution, the selection of resistent mutants should be added.

5. Thermal pollution.- Energy use by man implies a source and a sink, a more steep gradient and, more or less locally, an increase of temperature. No matter how the thing is presented, an increase of the temperature at which (biological) exchange happens, means a higher "production of entropy", a lower efficiency of transfer, an increased metabolism, and a lower ratio production/biomass. We find again the same result of human interference, and a lowering of diversity is to be expected too. The only foreseable exception in the last prediction could happen if heath output were organized in such a way as to stabilize natural ecosystems, giving off more heath in winter than in sommer, but this is not what usually happens in the instances of thermal pollution.

6. Radiactivity.- Ionizing radiation destroys a fraction of structure, but the structure left can continue activity and even increase it, profiting from "cleared" space. The predictable consequences of radiation, are a higher production/biomass ratio, and a lower diversity. Indeed it has been found that radiation lowers diversity in communities of plants and of soil animals, and such effect may be quite general. The increased concentration of chlorophyll observed in cultures of some species of algae, subjected to radiation, is consistent with the expected increase of turnover in radiated systems. Radiation affects interaction between species in the expected ways: in systems formed by a predator and a prey the predator is more depressed; in competion experiments, radiation favours the r-strategists (Auerbach, 1958; Blaylock, 1969).

All or most of the ways in which man interferes with the rest of nature, produce coincident or parallel effects. Diversity is reduced, horizontal transportation is increased, and the ratio production/biomass is increased also. If placed from the point of view of the non humanized ecosystem, accumulated and preserved organization can be considered as some measure of progress, it is claar, then, that forcing more energy through the system leads to a degree of simplification and inefficiency. The parallelism of change and its logical coherence represents a welcome simplification of the whole set of problems.

It can be said, in a very general way, that any system tends to internalize activity and develop homeostasis. When a system is exploited, it is forced open, and the changes that follow can be linked to its openess. But any open system becomes a part of a larger system, that itself can be relatively closed, or less open than the first one. In other words, and translating this in usual ecological terms, if there are general trends in succession, expressable through the maximization or minimization of definite variables, the same trends have to be recognized in the continuation of succession in the new system formed by the addition of man to the natural ecosystem. This would need often a reconsideration of the variables to be maximized or minimized, or of the selection of appropriate guide functions. Following such reasoning, inclusion of man must enlarge, and not damage, ecological theory. What I mean may become more clear through the following proposal: The function primary production/total biomass may be useful as a guide function in ecosystems in general, and specifically in non humanized systems. But in humanized systems, the guide function, to be predictive,has to include some human activities (we see later that they are not as exclusively human as it seems, and there may be advantages for general ecology in developing this point) and might take following form

$$\frac{\text{primary production+exosomatic metabolism}}{\text{biomass + artifacts relevant in survival}}$$

The mentioned artifacts expand influence over space and time, and are not different from strategies in evolution that combine events, through lengthening of individual life span, or through a more extensive use of an heterogeneous space.

In less abstract terms, human action can be viewed as a source of regression, as something that works again or runs contrary to succession, to the way towards a climax, a climax defined, of course, in the frame of non humanized systems (just as the minimum of the ratio primary production/total biomass). If exploitation plus interference in general, are in opposite terms with ecological succession, as usually understood, the consequence is to make any proposal for an absolute conservation an illusion. This needs a careful definition of conservation in every instance, always stating the allowed impact. Human activity, in general, can be considered as a "stress", that moves back the rest of the system - the "natural" system, that is- , opening it and coupling it with man as the exploiter, into a new system, in which eventually regularities in succession can be discovered.

The notion of stress might be useful, when ecosystems are considered as homeostatic systems. Stress is something that puts into action the mechanisms of homeostasis. Adequate models, along these lines, can be developed for almost any system. As an example I propose to consider the eutrophication of lakes. In aquatic ecosystems a number of homeostatic or stabilizing mechanisms can be identified. If a cybernetic description in terms of trends (or "goals") is not found abhorrent, it could be said that such mechanisms work to keep at a rather low level the primary production of plankton. For the purpose of presentation, parts of the mecanimss can be taken apart, but this procedure hardly does justice to the intimate coupling between manifestations that we tend to isolate. We can discuss several pieces of mechanism or brakes: 1) The selfscreening of plant pigments. The amount of active chlorophyll is limited to about 3oo mg/sq m, and so is primary production limited. 2) The oxygen or photosynthesis valve. High production leads to oversaturation in the surface layers, leads to the diffusion of oxygen from water to air, and to interception of flow of oxygen from air to water. As a result, part of the synthesized organic matter is not oxydized, and this amount is not related with production in a linear way. The percentage of produced organic matter that finds its way to become incorporated into the sediment, increases as production increases. 3) High productivity increases pH, and a part of the phosphate is taken out, mainly in form of calcium compounds. Mineral phosphate keep accumulating in the sediments of eutrophic lakes as well as below the upwelling areas in the oceans. 4) Any excess of nitrogen compounds -specially after part of the phosphate has been precipitated- leads to a more active denitrification. Nitrogen is passed to the molecular or atmospheric reservoir of the element; its way back goes through nitrogen fixation by bacteria and blue green algae.

From extrapolation of the workings of these pieces of mechanisms, that are always non linear, it can be anticipated a slowing down of the cycles, and the minimization of the energy exchanged per unit of preserved organization. This is a trend materialized in ecological succession, but we can see here how stabilization and succession appear as results of the same mechanisms. If we put the system back, immediately we reactivate mechanisms that were still working with lesser activity, "creeping towards climax". In particular, any bypass, like the ones of carbon and phosphate through sediment, or nitrogen through atmosphere, acts as a brake or as a buffer. It works actually as an hydraulic buffer or damper. Of course, the concept may be useful in describing human action. Man sets temporarily stores of elements out of the natural systems; any lengthening of the pathways amounts to the same. This means that acceleration of natural cycles by man cannot be as high as man intends to.

The workings of the proposed mechanisms can be visualized at best, studying the development, in mutual interaction, of the vertical profiles in the distribution of light, nutrients and plankton, in water, as well as in the development of terrestrial vegetation. Trees grow in heigh, by success of illuminated branchs in competition, and in doing so expand in the vertical dimension the path followed by elements in their cycle. Always, the most probable final situation is of a low primary production. In fact it seems lower than actually is, due to the difficulties of measuring it appropriately in very mature ecosystems. Another important point is the development of a mechanism of vertical transport. It becomes necessary and limiting, and at the end, without a more active participation of organisms (migration, evapotranspiration, activities of man) it might tie down energy flow at very low levels, allowed by physical diffusion. In very "mature" systems the vertical transport system seems well organized and in such a way that the whole system can be spatially decomposed into a number of vertical prisms or columnar systems, placed side by side, and almost independent. This does not mean, of course, that there is no exchange between adjacent blocks but only that, if there is such exchange, it is symmetrical: approximatively equivalent amounts of matter and of energy and of organisms go both ways.

We could imagine a highly hypothetical "climax" condition, with a minimal energy exchange, and a rigorous vertical organization of the transport system, just as described, and ask what keeps any system *from coming down to such state. In fact the* biosphere is a mosaiclike structure, and everywhere there are spots of high productivity, associated usually with a depression in values of diversity and a not so advanced differentiation in layers. Now, any increase in net production is associated with a particular input of energy that can be qualified as auxiliary or ancillary, and that is not the electromagnetic energy of light. Such auxiliary energy comes in form of seasonal mixing in lakes, tides in the littoral zone, general marine circulation in the upwelling areas, drainage from croplands and towns in eutrophic lakes, transport of soil and fertilizers by water in lowland countries. I propose that a measure of stress might be the auxiliary energy involved. Response to stress is an increase in primary production (usually), and a more important increase of the fraction of the product that is taken out of cycle, at least temporarily -this is the reason for seeing in the process a stabilizing mechanist- . It is clear that auxiliary energy is strictly associated with some measure of horizontal transport, and moreover that the input of auxiliary energy needs a minimum horizontal size to be realized: obviously an eutrophic lake cannot be modelled by itself, but has to include the area from which nutrients come, and obviously an upwelling system requires the study of a large marine area to be understood. It can be suspected that there is a definite relation between the (forced) primary production and the auxiliary energy involved (Margalef, 1973b).

Man is a species characterized by its ability to tap and put into action exosomatic energy, and is able as well to drive such energy in ecosystems. Such activity is associated with exploitation, through a forced primary production. It is noteworthy that a plotting of yield of crops versus auxiliary energy, such as depicted in the book of Watt (1973), comes closely to my mentioned graph (Margalef, 1973b). The slope may be slightly different, but this is to be expected, because crops receive also energy in rain, water trasport, and not only through the work of man, beasts and tractors. The stress exerted by man and manifested in destabilization and regression of natural ecosystems may be equated with the effects of fluctuating climates, erosion and silting, upwelling, etc. I submit as an important subject the careful study of the necessary relations between input of auxiliary energy and the transport involved, manifested in the minimum horizontal dimension required to funnel or to make effective a given amount of work.

It seems intuitiv, at least to me, that

in a fluctuating system, or in a system formed by parts disjointed in space, but functionally connected, the diversity computed over samples that cover small blocks of space and time, has to be smaller than any diversity computed over the whole system, or of any comparable ecosystem less seasonal in its aspects or more uniform in space. If the upper limit of diversity (about 5 bits per individual in biotic diversity) is an asymptotic measure of the organization to be expected in a relatively closed system, any transient of such system should display a lower diversity. Exploitation and enhancement of horizontal transport has to result in a decrease of diversity in the exploited system.

Any attempt to prediction has two aspects:

1) The common consequences of exploitation, interference in general, enhancement of the input of auxiliary energy, and asymmetric acceleration of horizontal transport are: reduction of diversity, acceleration of turnover, and increase of the mutual dependence of systems far away in space -and in time, remember fossil fuels-. This is what happens and is expected to continue, at an accelerating pace. Ecosystems that never have gone through the selection of serious environmental stress, as tropical forests, coral reefs and oligotrophic lakes, will be the firsts to go. The amount of interference that a system can support is linked non linearly to its state. To produce a certain amount of change, it takes much less pollution in an oligotrophic lake than in an eutrophic one. Stressed ecosystems are more resilient to increased stress and can absorb more disturbance -short of final catastrophe?-.

2)Other aspects of prediction have to consider behaviour of man, more as a peculiar species of mammal than as a rational being with high qualifications. It can be anticipated that exosomatic metabolism will increase much more, and that natural ecosystems will continue to regress. Perhaps energy will take away the temporary brake provided by pollution. As exosomatic metabolism continues to be basically inaequal and injust, and in a certain way proportional to population density, conurbations will continue to grow, until perhaps to kill themselves. It seems difficult to anticipate success for more rational, reticulated, organization of space. Prediction based on sketched theory goes only to the point when cultural artifacts become useless and the whole culture becomes noise. Loss of grip, then, may become rapid, and signify"doomsday"for a species that feels overconfident. If anticipation is related to reflection, in the frame of a feedback mechanism, we are much in need of some reference value for maintaining a healthy feedback. I am inclined to believe that the implied values of reference have to be based more on moral considerations and restraint, than in the simple play of power.

<u>References</u>

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