Considerations on the Ecological Effects of Xingu Dams

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Introduction

THE CONSTRUCTION OF a system of dams on the Xingu River (Eletrobrás and CENEC 1980) will mean important alterations in the levels of the area's terrestrial and aquatic ecosystems—one of the most complex (Golley 1983), least known and studied (Halle et al. 1978), and most threatened on the planet (Caufield 1984; USA NASA 1985). The sum of the average discharges of the Danube, Po, Rhine, Nile, Loire, Seine, and Ebro rivers represents approximately the average discharge of the Xingu. In these circumstances, the building of a system of dams—as well as the resulting ecological impact in terms of area flooded, alterations in the hydrological behavior of the river downstream, and the development of economic activities inherent to construction—will have a crucial effect on the future functioning of these systems.

Ecological impacts are unavoidable in the construction of any dam, although its negative effects are frequently presented after the fact as *unforeseeable* when in reality they were merely *unforeseen*. In Brazil, the procedures currently utilized to measure the ecological impact of development projects are still little developed, and the pertinent legislation is insufficient. In view of this situation, legitimate concerns have been voiced not only from all segments of Brazilian society but also from around the world: that the ecological dimension in dam construction is belittled and insufficiently treated. This concern is justified; the situation brings together, on the one hand, a large-scale project in an ecologically complex and little-known region and, on the other, the tradition of state authoritarianism (Projeto 1987; Monosowski 1983) in the execution of such projects (Vieira 1984; Brasil s.d.). This chapter introduces some objective data on this question.

The problem is not new—neither in Brazil nor in the rest of the world. Since the 1950s, planning and political decisions in other countries have sought to establish the real ecological implications of dams. In the United States, the process has specific characteristics (Legore 1984); in Canada, others (Effer 1984), which in turn differ from the procedures of the European Economic Community (Lee and Wood 1984). But there are major points of convergence. Our concern is not to condemn or justify a system or proposed project, but rather to include an analysis of the dam's probable ecological impact relative to the project's decision and execution—the same as you would include analyses of economic, social, and financial impact. This process allows, through adequate scientific methods, a detailed and precise dimension to the conflict existing between utilizing and conserving natural resources. It is what is called the *evaluation of ecological impact* (Canter 1984), or *environmental impact*, as some authors term it.

The term *environmental* suggests several reflections on the ambiguity and use to which this term has been put. For ecologists, an environment doesn't exist in strict terms, unless one clearly defines one or several forms of adaptation. A single phenomenon of ecological disequilibrium—the eutrophication of a lake due to problems of pollution, for example—has distinct meanings depending on the environment considered. For the fish, the results are tragic since algae proliferate in an almost unlimited manner in the new context, to cite only one example.

MANY AUTHORS SAY that when the effects of humans are added to the evaluation of ecological impact, the study becomes environmental. The main reason stems from the fact that the human population bears characteristics completely distinct from other animal populations, including its relationship to nature. A human-nature relationship does not exist; it is, rather, a relationship among humans through nature. In this sense, nature ought to be considered as the object of social relations, not as an end in itself. Every crisis in the use of nature is simply a reflex of a crisis in social relations.

In introducing "man" or "communities" into their studies, the supposed environmental impact assessments seek to have projects determined by restricted social groups accepted. These groups see in nature an object capable of affirming, extending, and perpetuating their own social position. Preferably, these problems should be treated by

specialists in the areas of anthropology, economics, and sociology. It is not up to the ecologists to venture into this field, or, worse still, to provide their services—consciously or not—to such dangerous propositions (Miranda 1984).

This process of assessment, whether it be in North America, Europe, or Japan, has little or nothing to do with what in Brazil is called the *Relatório de Impacto sobre o Meio Ambiente (RIMA)* ("Impact Report on the Environment"), extremely insufficient and limited in terms of clarifying the conflict in question, when it is duly presented. The experience with the RIMAs completed for other dams, above all in the north and northeast regions of Brazil (Eletrobrás 1986), would be even one more motive for concern in the case of the Xingu River (Monosowski 1983; Schaeffer 1986).

For the purposes of illustration, this chapter brings together some reflections on what would effectively represent a process of ecological impact assessment for a project such as that planned for the Xingu River, were it to be implanted in a developed country (Edwards 1984) or even in certain underdeveloped countries (Monosowski n.d.). We attempt to apply in this case the same methods used in Thailand (Manual of NEB 1979).

IN THAILAND, IN 1975, the National Environmental Quality Act (NEQA) created the Office of the National Environmental Board (ONEB), more or less the equivalent of what in Brazil would be the National Council for the Environment (Conama) (Brasil 1984/86). Thai law, however, establishes a procedure for approval of environmental impact studies very different from the Brazilian case (Brasil 1986), and shows that the ONEB has broad powers of decision and regulation. In the case of environmental problems, the analysis is done before the projects are approved. The proponent initially prepares the Terms of Reference (TOR), which contain specific requirements for that project. The TOR is examined by the NEB (National Environmental Board), connected to the ONEB, and must be approved so that the proponent can receive direction and authorization to prepare the EIA, the environmental impact assessment. In general, some agency or institution with proper credentials prepares the EIA, which will be approved or rejected by the NEB in 90 days. If rejected, the proponent will revise the EIA on the points required and will resubmit it to the NEB, which reexamines it within 30 days. As long as the project does not fulfill any of the stages under the NEB's responsibility, it must return to the preceding stage. If approved, the result is sent to the government, through the Parliamentary Cabinet, whence it will proceed through the National Economic and Social Development Board and, from there, to the relevant ministries. Only after the project passes through all of these stages will the government decide on its execution.

In truth, it seems difficult to admit that a country such as Brazil, which makes a point of boasting its title of the eighth largest economy in the world, cannot emulate what is being done in this field in Southeast Asia—above all, because this concern has been turned into one of the requirements for project financing (World Bank 1983). A recent issue of *Science* magazine addressed the changes in World Bank policy in relation to the environmental question, using as an example the case of the Brazilian Amazon, where the impacts of development projects on ecology and indigenous populations (Walsh 1986) are specifically considered (Magalhães and Hummel 1987). It is clear that the ecological impact of the Xingu project (loan areas, construction works, containment dikes, roads, transmission lines, etc.) is somewhat greater and more complex than we address in this chapter. Here, through a small example, we seek first to illustrate the importance of the ecological question, now and in the future. In the second part of this chapter, we will analyze the direct ecological impact of the lake to be created on the several terrestrial and aquatic ecosystems in two locations of the region by applying part of an internationally utilized and recognized method: the Habitat Evaluation System (HES) (US Army Corps of Engineers 1980). This study presents a numerical and cartographic qualification and quantification of this impact on the locales referred to and the principal consequences for the fauna of these habitats.

In conclusion, we will discuss some minimum requirements that any Brazilian would certainly agree to—we live on one and the same planet, and this dam affects one of its most delicate parts. Would that those responsible for the project and the executors of the project also share them!

Methodological Aspects of Ecological Impact Assessment for Dam Construction Projects

The parameters utilized internationally in assessing dam projects' impact on the environment are well-established, perhaps better than for any other kind of project. The reason is simple: dams and their reservoirs profoundly alter the environment. Their impacts are differentiated in time, and they affect distant regions, both upstream and downstream from the site, in irreversible ways. To such a degree it is standard in other countries to require, for the environmental question, a detailing of the studies in stage A, which is only required at this level for other segments in a later stage, stage B. On the other hand, experience shows that in those countries which duly conducted impact studies, not only were the projects' main objectives achieved, but gains were made in energy production, agricultural production, flood control, water supply, navigation, the quality of life of the populations, and so on—with a minimum of environmental losses.

For humid tropical regions, even Thailand offers

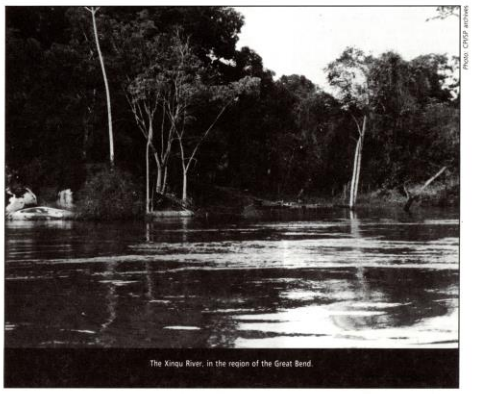


Photo: CPISP archives

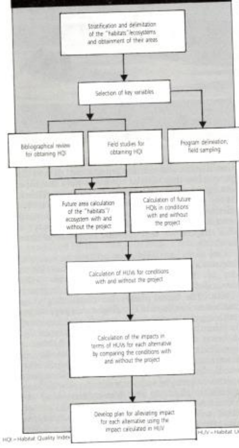
The Xingu River, in the region of the Great Bend.

valid examples as initial points of reference. The Pa Mong Optimization and Downstream Effects Study, prepared by the Committee of Mekong in 1976, and the Environmental Study of Nam Pong Dam and Reservoir Project of 1978, despite their having been done more than 10 years ago, still have great relevance to the Brazilian case. The fact is that the dam and its reservoir, electrical production and its transmission, and rural development inherent to the project ought to all be evaluated together. This impact assessment in countries such as Thailand involves the *physical resources* (hydrology of the surface waters, quality of the surface and subsurface waters, soils, geology, seismology, basin erosion, sedimentation in the reservoirs and tributaries, local climate, etc.), the *ecological resources* (terrestrial and aquatic flora and vegetation, terrestrial and aquatic faunal populations and population areas, fish, forests, aquatic biology, etc.), the *use values for the society* (navigation, electrical energy generation, water supply, irrigation, agroindustry, mining, tourism, flood control, aquaculture, agriculture, diversified use of lands, roads, and railroads, etc.), and the *elements of importance for the quality of life of the populations* (settlements, relocation of populations, archaeological sites, public health, endemic diseases, nutrition, historic and cultural aspects, etc.). It is in this perspective that various countries have developed ecological impact assessments for dams (Schorr 1984; Canter 1985; Canter et al. 1987). The methods utilized, although diversified, converge toward the same end. Given the limited scope of this chapter, we will consider only one of these methods.

One of the methods most utilized for assessing impacts at the level of ecosystems and habitats today is the Habitat Evaluation System (HES) developed by the US Army Corps of Engineers (1980). The basic phases for conducting these studies are outlined in the diagram on page 80. For utilizing this method, it is assumed fundamentally that the presence or absence, abundance and diversity of an animal population in a habitat or community are determined by basic biotic and abiotic factors that can be easily quantified. In other words, the carrying capacity of a habitat for a given species or group of species is correlated with basic chemical, physical, and biotic features of the habitat. Although more complex biological interactions, such as predation, competition, and sickness, also affect wildlife populations, the HES assumes that if the necessary requirements for a species exist in a given habitat, then a viable population of this species will be—or potentially will be able to be—supported by this habitat. The HES considers groups of species and size of habitats, and the quality of these are combined to evaluate the project impacts at different levels.

As can be observed in the figure, the first step is to describe and obtain the types of habitat and land use for the areas. This makes the calculation of the "Habitat Quality Index" (HQI) viable, through the key variables for each habitat, as, for example, the index of sinuosity of rivers, the utilization of "Paired Weighting Systems" for terrestrial ecosystems, and so on. The third step is to calculate the possible "Habitat Unit Value" (HUV) to be quantified through a broad-based review of the literature (including reports, satellite photos, aerial photos, cartographic documents, etc.) (Miranda et al. 1986). In selected cases, the work includes only the data necessary so that the calculations of these indices can be made in a future field study. As another step, the projection of these HUVs is made both with and without the project conditions, and these same units are utilized to assess the impact of the different alternatives. In certain locales or alternatives for dams, the analysis of ecotones can be used to predict biotic productivity through the calculation of the "Edge Index" (EI). The "Edge Indices" are utilized for a basic description of the effects of the most destructive alternatives on terrestrial biota. In conclusion, the set of these assessments is synthesized and the basic requirements that could permit the correction or limitation of undesirable ecological effects are determined.

Basic Stages in Conducting an Impact Assessment Based on the Habitat Evaluation System



Preliminary Evaluation of the Impact of the Xingu Dams on Terrestrial and Aquatic Habitats

A Portion of the River and a Part of the Method

This chapter could not apply the methods for habitat evaluation to the totality of the area affected, directly or indirectly, by the system of dams on the Xingu River—we would not have the means to do this, nor is this the purpose of our chapter. It would be up to those responsible for the project to apply not only this method but also the entire set of analyses that characterize a process of ecological impact assessment. Also, the few documents available (topographical maps, satellite images, etc.)—without field surveys with the necessary resources—did not, in this case, permit the application of the totality of the habitat evaluation method (Brasil 1980).

Nevertheless, by way of illustration, and in a preliminary way, an initial evaluation of the habitats that exist and will exist after the construction of the dams was prepared for two distinct areas of the Xingu River. The perspective for ecological change has been minimized. Many habitats about which there were doubts were not mapped, despite the absolute certainty of their existence. It was preferable to stick to what appeared as indubitable in the few documents available, without considering the indirect ecological impacts of the dam construction. Certainly, in the areas studied, the habitats are more complex and possess features not detailed in this chapter. But, even so, this minimum of ecological qualification and quantification of the area allows for illustrating the magnitude of the direct ecological impact of this undertaking, even though only a portion of the river is being considered through a part of the method for assessment of habitats. For this, the following representative areas near Altamira (Pará) were analyzed:

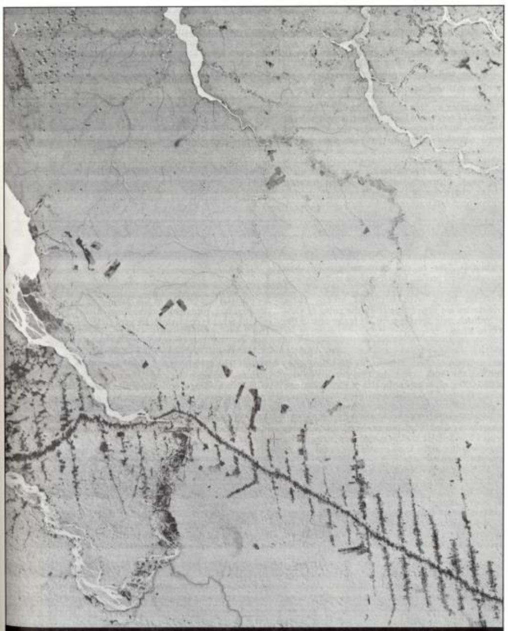


Photo produced by LANDSAT-5, on 15 July 1986, shows the Great Bend, where the Xingu Hydroelectric Complex will be built. The large, light area of the photo shows the density of the forest broken by the tracing of the Trans-Amazon Highway and the indiscriminate deforestation accompanying the clearing for ranches.

area 1—Babaquara Reservoir
map 1: 340–370 & 9,625–9,645 UTM*
map 2: 340–370 & 9,600–9,620 UTM
area 2—Cararaô Reservoir
map 3: 410–440 & 9,625–9,645 UTM
map 4: 410–440 & 9,600–9,620 UTM

*UTM = Universal Transverse Mercator

Terrestrial and Aquatic Habitats on the Xingu

Occupying an area of 6.5 million km² (approximately 57 percent of the European continent), the Amazon River Basin constitutes the largest and most complex system of river drainage on the planet. Given the characteristics of the region, which contains a good part of the earth's pluvial precipitation and has a slow drainage as a result of the weak altitudinal gradients of the Amazon Plains, the rivers of this basin are permanently voluminous and responsible for maintaining extensive areas of seasonal inundation.

The local base level, the Amazon River, is the main sink for the runoff from important tributaries that drain part of the Guiana Highlands to the north, and from the southern Amazonian highlands. Due to the characteristics of their topographical profile, which include sections with sharp alternation of altitudes (contacts of the Amazon Plain with highland areas), these tributaries are interesting from the point of view of hydroelectric development, as is the case of the Xingu River.

With a length of 1,500 km from its sources in the Brazilian central highlands to its mouth on the Amazon (the equivalent of double the Rhine River and half the Volga River), the Xingu drains an area of 540,000 km², or twice the size of West Germany, with a flow of 7,100 cubic meters per second running through important indigenous areas in the state of Pará. This river belongs to the group of Amazonian rivers called "black-water rivers," that is, those with a low detritic load in suspension, even in the rainy seasons, and consequently a reduced rate of dissolved mineral salts.

When the reservoirs of the Xingu Hydroelectric Complex are formed, important natural areas will be flooded, diverse habitats that have been preserved from anthropic action, most of which are the result of fluvial action over the last 5 million years.

Based on the available documents, it was possible to detect, qualify, and quantify about 30 different habitats in the two areas studied. The cartographic results are shown on Maps 1, 2, 3, and 4 presented in the appendix. Despite their preliminary character, these results illustrate the magnitude of the ecological problem that the dams will cause. With more information, it would certainly be possible to go into greater detail; perhaps the number of habitats to consider would be closer to 50 (Bailey 1985). This is a figure which in itself illustrates the ecological diversity of a river the size of the Xingu. In temperate climates, rarely does one get 10 habitats, which are characterized by a much poorer display of fauna and flora. The main habitats detected and mapped will be the object of a succinct presentation, above all with reference to their status with and without the dams. Table 1 summarizes the essence of these results in the present situation. Table 2 presents the probable qualitative and quantitative evaluation of these habitats after the construction of the Babaquara and Cararaô dams.

Impacts on the Faunal Populations and Population Areas

As we have seen before, the area near the dams of the Xingu has a great diversity of habitats—approximately 50—some almost unequaled in the Amazonian world. Almost all of the habitats located at the level of the Xingu River channel will be submerged where the system of dams foreseen by the hydroelectric project is implemented. The number of faunal populations specific to these habitats is very important; it has the notable feature of belonging to one of the most complex ecological systems in terms of fauna/vegetation relations (Begon and Mortimer 1981).

In the habitats offered by the fluvial and riverine environment, principally in the Xingu River Channel, the faunal populations are very characteristic. The levels of the banks, secondary channels, islands, sandbanks, and so on abound in numerous aquatic and marsh birds, principally the *maguari* (*Ardea cocoi*), various herons, the cormorant (*Anhinga anhinga*), the jacana (*Jacana spinosa*), and so on. On the Xingu, gulls (*Phaetusa simplex*) hunt on and frequent the sandy beaches, as do large numbers of wild ducks, which feed and reproduce in the biotopes offered by the flood lakes, intra-island lakes, and marginal dikes, which will disappear totally.

Sandbanks and islands are habitats of reproduction, obviously vital for the subsistence of species. Each year in these habitats, large freshwater turtles lay thousands of eggs, such as the *Podocnemis expansa*, which reaches a weight of 70 kg and lays between 80 and 200 eggs at a time. It is enough to point out that even the populations that live in the tributaries of the Xingu are capable of migrating hundreds of kilometers to lay their eggs in the sandbanks of the river each year. Without adequate measures, the dams will present an insurmountable obstacle for these animals, as well as others that circulate through the river (fish in spawning). Populations that lived in interaction will be transformed into subpopulations at the level of each lake formed by the dams. There are even certain species of birds, such as the *batuiras* and *bacaraus*, that build their nests at the level of the islands due to the absence of predators in this kind of habitat. The chicks are raised in these locales until they reach adult age.

With the disappearance of these habitats, the

faunal populations will undergo very important qualitative and quantitative changes, as in the case of the giant turtles, the avifauna, and crocodiles (*Caiman crocodilus*—nearly 2 meters in length). They will suffer extreme changes in their population dynamics as they lose a large part of the habitats in which they reproduce and raise their young.

In the aquatic habitats, there are notable ichthyological fauna, such as the giant pirarucu (*Arapaima gigas*), the largest freshwater fish in the world, and the piraíba (*Brachyplastytoma*), as well as numerous species highly appreciated for their excellent taste, such as the tambaqui (*Colossoma*) and the tucunarés (*Cichla*). The banks of the Xingu, as well as its tributaries, bring together ecologically favorable conditions for large numbers of birds and mammals to feed and reproduce on, as well as invertebrates, fish, batrachians, and reptiles, among which are riverine anacondas, boa constrictors, and crocodiles (Pádua and Coimbra Filho 1979).

A significant number of mammals spend a great part of their lives in aquatic habitats (riverbanks, canals, streams, etc.), swimming, immersing, or looking for prey or for shelter: freshwater dolphins, or botos (*Sotalia* and *Inia*); otters (*Lutra*), and the largest of all known otters, the *Pteranura brasiliensis*; tapirs (*Tapirus terrestris*, large mammals that can weigh up to 180 kilos and spend the greater part of their time in water, feeding on algae and river-bottom vegetation; and the largest rodents in the world, the capyvara (*Hydrochaerus hydrochaerus*), which weigh about 60 kilos and live on the banks of the Xingu, its tributaries, and in the perennials and flood lagoons. The capyvara is exclusively herbivorous and represents, together with the tapir, an

Table 1
Preliminary Qualification and Quantification of the Terrestrial and Aquatic Habitats of the Xingu River, Altamira Region (PA)

	Area 1		Area 2	
Habitat	**Map 1**	**Map 2**	**Map 3**	**Map 4**
Main river (km)	32.5	36.5	16.0	34.5
Main river (ha)	5,925.0	2,300.0	1,100.0	6,200.0
Sinuosity index	2.1	2.3	2.0	2.4
Minor channels (furos) (km)	0.8	37.0	0.0	1.5
Sinuosity index	1.0	2.9	–	1.0
Paranás (km)	37.0	97.0	82.0	61.0
Sinuosity index	1.9	2.3	2.1	2.5
Igarapés (km)	210.0	293.0	328.0	332.0
Sinuosity index	2.5	2.1	2.4	4.0
Tributaries (km)	–	–	–	25.0
Sinuosity index	–	–	–	3.6
Rapids (no.)	1	1	1	3
Island lake (no.)	25	48	1	37
Várzea lake (no.)	2	2	43	18
Endorréico lake (no.)	1	2	3	5
Islands (no.)	62	178	139	320
Rivermouth island (no.)	–	–	–	1
Tributary island (no.)	–	–	–	18
Island bank (km)	86.2	325.0	7.5	85.0
Island ravine (km)	12.0	23.5	3.5	29.0
Island beach (km)	22.0	43.0	21.0	23.0
Fluvial beach (km)	4.5	21.0	9.5	29.5
Várzea bank (ha)	375.0	–	187.0	450.0
Abrupt margin (km)	90.0	161.0	137.0	213.0
Alluvial plain (ha)	4,525.0	4,950.0	4,870.0	4,000.0
Raised shorelines (ha)	5,550.0	2,300.0	4,510.0	2,050.0
Terra firma–glacial (ha)	74,822.0	64,782.0	71,870.0	78,965.0
Terra firma–hills (ha)	–	–	10,060.0	–
Plained toplands (ha)	–	5,847.0	1,312.0	1,275.0
Total areas (in hectares)	145,451		163,482	

important source of protein for the indigenous and riverine populations.

In the terra firma habitats occupied by broad-leafed foliage, even the habitats of the beaches and riverbanks abound in reptiles such as the gigantic crocodile (*Melanosochus niger*), which can reach lengths of 6 meters and which has an important role in controlling piranha populations. In the areas of less dense forest live land turtles (*Geochelone tabulata*), which represent an important food source for the indigenous populations.

Among the principal terra firma mammals are the jaguar (*Panthera onca*), the largest feline in the Americas, which weighs around 100 kilos. There are also anteaters, among which one finds the striped anteater (*Mymercophaga tridactylus*), the largest of the family (weighing approximately 70 kilos), and the anteater (*Tamadua tetradactylus*), which is very numerous in these terra firma habitats. Among various species, the cervidae (*Mazama gouazabira*); the peccary (*Tayassu peccari*), equivalent to the wild boar in neotropical regions; and various armadillos, including the giant armadillo (*Prodontes giganteus*), which can weigh up to 70 kilos; are all exploited as protein sources and for commerce.

Table 2
Qualification and Quantification of the Probable Terrestrial and Aquatic Habitats After the Construction of the Babaquara and Cararao Dams on the Xingu River, Altamira Region (PA)

	Area 1		Area 2	
Habitat	Map 1	Map 2	Map 3	Map 4
Main river (km)	32.5	36.5	16.0	34.5
Main river (ha)*	16,709.0	11,843.0	9,390.0	16,172.0
Sinuosity index	1.5	1.0	1.0	1.5
Minor channels (furos) (km)	0.0	0.0	0.0	0.0
Sinuosity index	1.0	1.0	1.0	1.0
Paranás (km)	0.0	0.0	0.0	0.0
Sinuosity index	1.0	1.0	1.0	1.0
Igarapés (km)	88.0	90.0	93.0	107.0
Sinuosity index	1.5	1.5	1.5	2.0
Tributaries (km)	0.0	0.0	0.0	0.0
Sinuosity index	1.0	1.0	1.0	1.0
Rapids (no.)	0	0	0	0
Island lake (no.)	0	0	0	0
Várzea lake (no.)	0	0	0	0
Endorréico lake (no.)	0	0	0	0
Islands (no.)	0	0	0	0
Rivermouth island (no.)	0	0	0	0
Tributary Island (no.)	0	0	0	0
Island bank (km)	0	0	0	0
Island ravine (km)	0	0	0	0
Island beach (km)	0	0	0	0
Fluvial beach (km)	0	0	0	0
Várzea bank (ha)	0	0	0	0
Abrupt margin (km)	36.0	49.0	58.0	83.0
Alluvial plain (ha)	0	0	0	0
Raised shorelines (ha)	0	0	0	0
Terra firma–glacial (ha)	72,972.0	60,457.0	68,345.0	78,190.0
Terra firma–hills (ha)	–	–	8,010.0	–
Plained toplands (ha)	–	5,200.0	1,312.0	1,275.0
"Future islands" (ha)	1,850.0	4,325.0	3,525.0	775.0
"Future islands" (km)	147	160	122	75
Total areas (in hectares)	138,629		157,032	

*Area corresponding to the lakes resulting from flooding, not presenting however the original features of the main river. This wasn't considered in the final totals.

Terrestrial and Aquatic Habitats: Predicted Alterations

The Main River

Given its altitudinal gradient, the Xingu River can be considered in its totality as a highlands river, since a large part of the sinuous line of its valley is located in the south Amazon highland. It can be considered to be the interface between the highland portion and the Amazon plain, the contact point between tertiary lands of the escarpment formation and paleozoic sediments of the Amazonian geosyncline. Rapids and waterfalls are common in this area, providing testimony of differential geological contact, forming truncations in the minor bed and the consequent appearance of distinctive deposits in the anterior portion and canyons of rapid runoff due to thresholds. This bar formation will be responsible for the appearance of a meandering bed, islands, cavities, and so on, as can be observed in Maps 1, 2, 3, and 4 in the appendix. In some areas of the Xingu, the clusters of diaclases are striking, providing testimony of a structural conditioning in the pattern of local drainage, giving rise to a system of specific islands (Map 3). Comparing Tables 1 and 2 shows that in the two areas there will be a complete change in this complex habitat that represents the sheet of water of the Xingu, corresponding to the loss of 69 km, or 8,225 hectares, in area 1, and 50.5 km, or 7,300 hectares, in area 2. This will be substituted by a sheet of water from the reservoir lakes covering 31,550 hectares in area 1 and 21,768 hectares in area 2. The spatial dimension of this habitat can be observed principally in Maps 1, 2, and 4, which show the diversity of fluvial forms subordinate to it.

The "Furos"

Minor channels which, in the várzeas, form a system of communications between the main river and its nearest tributaries, between várzea lakes, and so on, the "furos" constitute in some areas a true fluvial network. Such features are the result of interfluvial breaks of the high várzea that drains the floodplains. By contrasting Tables 1 and 2, we see that the furos will totally disappear, corresponding to 37.8 km in area 1 and 1.5 km in area 2. Although presenting difficulties in their identification on the scale used, their significant presence can be noted on Map 2, on the lower portion next to a substantial island sandbank.

The Paranás

Acting as complementary waterways to the main runoff, the paranás consist of extensive, wide, deep branches of large rivers which on the floodplain form a large island. They are called *paranás* in the region (*para* "sea"; *nás* "similar to"). They are derived from the wandering of the minor bed over the alluvial plain, abandoned as marginal fluvial segments (see Map 3). It can also be observed from Tables 1 and 2 that these habitats will be completely compromised, given that a total of 134 km in area 1 and 143 km in area 2 will be covered by the dam's waters. The presence of this habitat is notable on all maps; however, it is worth noting its prominence in relation to the main river in the central portion of Map 2.

The Igarapés

These are short, narrow water courses with well-defined basins, found in both várzea and terra firma (from the Tupi: *igará* "canse"; *pé* "trail"). They consist of elements more from the drainage of tertiary plateaus than from the várzea (see Map 2). They are responsible for the removal of sediments from tertiary drain surfaces, conditioning the evolutionary role of the footplain slopes. They contain very typical fauna and vegetation. The comparison of Tables 1 and 2 shows the disappearance of 324 km in area 1 and 460 km in area 2 after dam construction. This habitat is densely present in all areas analyzed, and is notable on the upper portion of Map 2, on both banks of the main river.

The Tributaries

These are canals of intermediate discharge for the large rivers and igarapés. Often, they are base level for considerable areas on the scale 1:50,000, presenting islands and sandbanks mainly near their mouths (see Map 4). Their downstream dynamic is governed by the debit of the main river. Tables 1 and 2 also show complete disappearance of the tributaries after the completion of the project, the loss of these habitats being on the order of 25 km in area 2. The sinuosity index will go from 3.6 (a value that indicates diversified biotopes) to the simplest possible value: 1. Map 2 shows an important tributary of the Xingu, the Bacajá River, occupying a considerable extent of space in relation to the area mapped, on the lower left portion of Map 4.

The Rapids and Cataracts

Differences in water levels produced by differentiated lithologic contacts give rise to rapids and cataracts (the latter present difficulties in their identification on the scale used), which, due to their particular hydric circulation, create zones of high oxygenation in the river bed. They are difficult to observe and map with the available documents, but their disappearance in the areas of flooding will be total. These habitats can be noted principally on Map 4, in its central position, and upriver and downriver of the Bacajá River.

(more)

Photo: CPISP archives

With the building of the hydroelectrics, the population that lives in the Xingu region today will be deprived of a whole tradition of knowledge that has been accumulated over generations—a loss that cannot be quantified or indemnified.

The Island Lakes

These appear on islands which have the same depositional dynamics as the várzeas, isolated by paranás; thus they result from the successive migrations of the minor bed (Map 3). The tables demonstrate that these habitats will completely disappear—73 in area 1 and 38 in area 2. With the exception of Map 3, these habitats are found on most maps; they can be especially noted in the upper portion of Map 4.

The Várzea Lakes

These are lacustrine depressions in the interior of the alluvial plains that contain large sheets of water in a progressive process of seasonal sedimentation. They are shallow-water bodies with a depth of 3 to 6 meters in high water, and 1 to 3 meters in low waters. They may have their formation associated with an abandoned meandering barred by sandbanks. They function as important reservoirs for part of the fluvial discharge during times of high water. A contrast of Tables 1 and 2 demonstrates that after the flooding, four várzea lakes will cease to exist in area 1, and sixty-one in area 2. Such habitats occur in all maps except Map 1, being most relevant in Maps 3 and 4.

The Endorréicos Lakes

These are characterized by lacustrine systems determined by successive deposits of várzea sandbanks, or by the deposit of sandy detritus load carried by streams from Amazonian tertiary tablelands. Many endorréicos lakes are found adapted to the network of regional faults, or built up by marine transgressions in the Pleistocene during the last interglacial phase. The irreparable loss of such habitats is shown by contrasting Tables 1 and 2: three lakes in area 1 will disappear and eight in area 2, the loss being total. Although they have a reduced presence in the areas analyzed, they can be noted in the upper portion of Map 4.

The Islands

a. Islands in diaclasis Elaborated on the basis of the differential action of erosion by the waters of the riverbed on fault zones of the lithological base, islands in diaclasis are delimited by these riverbed branches that isolate immersed portions of rocky material, exposed or recovered by fluvial detritus (sands, gravel, etc.). Generally, they are found in areas of rapid fluvial runoff due to distinct lithological contacts, for example, upstream from the future Cararaô dam, but are

difficult to map on the basis of the documents available. They should increase after the dams are constructed, and will come to have a hydric dynamic very different from their present one. The islands in diaclasis are striking in the upper portion of Map 3, where structural control in the morphology of local drainage is visible.

b. Islands of detritic accumulation These are topographical forms situated in the bed of the canal, formed by the interaction between water flow and movement of sediments, resulting in irregularities produced in the bed of the alluvial canals. They are comprised mainly of sandy gravel particles interspersed with fine material (silt, clay). They can be related to phases of anastomosed morpho-genetic features on the lithological barring of the bed bottom (thresholds, etc.). They are environments of rapid mutability due to the inconsistency of the constituent material. Almost all the islands mapped fit into this case, which in determined portions of the river constitutes an impressive complex whole (Map 4).

The quantification of the disappearance of these islands in the two areas analyzed amounts to a total of 240 in area 1 and 459 in area 2, the loss being total. It is important to point out the dense presence of such habitats in the lower left portion of Map 4.

b1. River mouth islands Formed by unconsolidated detritic material, these have developed due to local difference in the velocity of flow between the main river and its tributary.

In periods of very high water, when the water level of the main river rises more quickly than that of the tributary, the process of "damming" the tributary waters occurs, restricting their velocity and provoking material deposits. These deposits are generally comprised of fine detritic material (clayey silt) in the immersed portion and gross material in the submerged base. This habitat, plainly visible in Map 4, will disappear after the concretization of the project. Map 4 represents a river mouth island of considerable spatial representativity, at the mouth of the Bacajá River.

b2. Tributary islands These islands correspond to type B, but are of smaller proportions, situated on tributary rivers of the Xingu. They are characteristic of the downstream portion of these tributaries, formed as much by the type of gradient (slow) as by the decrease of velocity of flow provoked by the local base level. Tables 1 and 2 show the complete loss of this habitat, amounting in area 2 to a total of 18 islands. In Map 4, along the bed of the Bacajá River, the importance of these islands can be noted.

c. Sand banks and island ravines These are fluvial depositional surfaces situated on levels topographically superior to the surface of the island, elaborated by the seasonal variation of the fluvial bed; in the period of high waters, there is a vertical rise and, in the period of low waters, lateral washout. The island ravine is created when the difference of level occurs abruptly at the island banks. These can be observed in the sections represented by Maps 1, 2, 3, and 4 in distinct locations and dimensions, of great importance for diverse faunal populations. Also, in Tables 1 and 2, the total loss of such habitats can be noted in the two areas analyzed, amounting to 411.2 hectares in area 1 and 92.5 hectares in area 2 for the sandbanks, and 35.5 km and 32.5 km, respectively, for abrupt ravines. Such habitats occur in all maps, and their marked presence can be seen in Map 2.

d. Island beaches Similar to the fluvial beaches in terms of genesis and evolution, the island beaches are features homologous to adjacent areas of island sandbanks and várzea sandbanks. The loss of this habitat corresponds in area 1 to 65 km, and in area 2 to 14 km of extension. Despite the difficulty in interpreting these habitats with the material available, their significant presence can be noted in Maps 1, 2, and 4.

The Fluvial Beaches

These are depositional features characterized by soft gradient, located on the banks of the large rivers, tributaries, and streams. They present a granulometric composition that can vary from fine sands to gross sands with gravel, resulting from recent sedimentation by nonsoluble detritic load in the water flow. This process is determined in most cases by the dynamics of local river circulation. An analysis of Tables 1 and 2 shows the total disappearance of this habitat. This habitat also presented difficulties in its identification; however, its presence can be verified in the lower portion of Map 3.

The Várzea Sandbanks

The successive inundations of the alluvial plains provoke periodic increments of sediments that may be similar to cordons or more extensive areas in topographically higher levels on the floodplain. These features are formed in the várzea sandbanks. During the process of dry weather, these may suffer erosion, thus creating forms in depression that can contain lakes or furos. When the várzea sand banks present semicircular forms, their genesis is associated with a development on the inner part of a meandering curve. In the specific case of the island sandbanks, fluvial degradation/aggradation action connected to seasonal behavior of the paranás can be observed. An analysis of Tables 1 and 2 shows the total disappearance of these habitats, representing 375 hectares in area 1, and 637 hectares in area 2. Except for Map 2, these habitats are notable on most maps, their occurrence being visible on Maps 1 and 4, on the left bank of the Xingu.

(more)

The Banks on Abrupt Slope

These are found in marginal areas where there is a direct drop in vertical slopes, with a strong declivity at the base, often funneling the runoff of fluvial canals when this unit of relief is repeated on both banks. In this case, frequently there are rapids or waterfalls when one is dealing with thresholds, resulting from the meeting of two interfluves in crest. It is a typical form of the headwaters of streams or in funneled portions of the main drainage, varying from thick colluvial deposit to exposed rocky bodies, depending on the decline. The results of Tables 1 and 2 show the partial disappearance of these habitats in the two areas, corresponding to 166 km in area 1, and 209 km in area 2. Present on all maps, their relevant occurrence can be noted on Maps 3 and 4 at the areas most distant from the main river.

The Alluvial Plain

This morpho-hydrological feature is formed by the successive deposits of sediments in suspension in fluvial channels when these are in the phase of seasonal overflow, corresponding to the periods of floods. It represents a drainage subsystem with difficult and disorganized runoff, even in the periods of low waters, conditioned by the dense and intricate grassy, arboreal, and shrubby vegetation that covers it. In the period of minimum inundation, a peculiar system of drainage occurs, characterized by the furos, lakes in process of filling up, and várzea lakes. Topographically, the alluvial plains present a minimum of rugosity with the exception of the occurrence of depositional features subordinate to them, such as várzea sandbanks or lacustrine depressions. This being the most significant habitat to be inundated, the comparison between Tables 1 and 2 shows considerable loss of these areas by flooding after the construction of the dams, the total loss being on the order of 9,475 hectares in area 1 and 8,870 hectares in area 2. The presence of this habitat is easily verified on all maps, with its main occurrence being visible on Maps 1 and 2 along the banks of the main river.

The Terraces

These features are found below the so-called "terra firma" and are also known as *tesos* (raised ground not reached by flood). They were formed during the Pleistocene era by deposits on paleo-alluvial plains that were reworked in the Holocene era, with colluvial-alluvial sediments contributing to their genesis. They are situated from 20 to 30 meters above the actual alluvial plains and do not suffer flooding. They are actually found carved by the dense network of streams that condition the appearance of small interfluves. Together with the alluvial plains, these habitats have a relevant spatial importance, but will completely disappear in the areas analyzed, corresponding to 7,850 hectares in area 1 and 6,560 hectares in area 2. Such habitats are present on all maps, and can be seen especially on Map 1, principally on the right bank of the main river.

Terra Firma

The complex of lands in which periodic flooding does not occur is known regionally as terra firma. This morphological unit presents local differentiations due to the lithology, responsible for the structuring of the relief in interaction with the climate. In this manner, terra firma of the convex hill type, maintained by Precambrian rocks of considerable resistance, are distinguishable from terra firma of the glacial type, characterized by broad surfaces of tertiary erosion, formed on solidified sedimentary rocks.

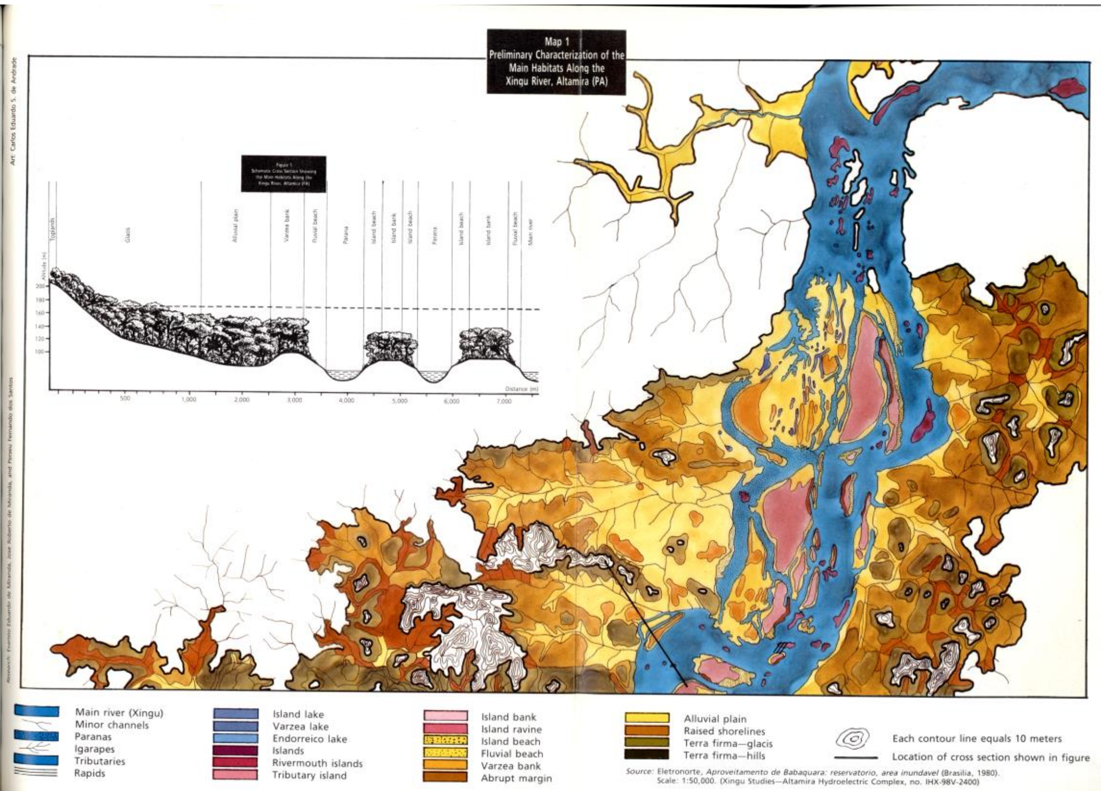
The hilly terra firma presents a relief dominated by abrupt slopes (where chemical intemperateness predominates), mass movements, and "V"-shaped valleys. The glacial terra firma, in turn, is characterized by gently inclining slopes, wide valleys covered by the streams and tributaries of the main river, and residual relief of pediplanation—that is, the planed toplands. An analysis of Tables 1 and 2 shows the partial disappearance of these two kinds of terra firma: for the glacial type the loss is 6,175 hectares in area 1 and 4,300 hectares in area 2; for the hilly terra firma, the area flooded corresponds to 2,050 hectares in area 2. This habitat is present principally in Maps 1 and 2.

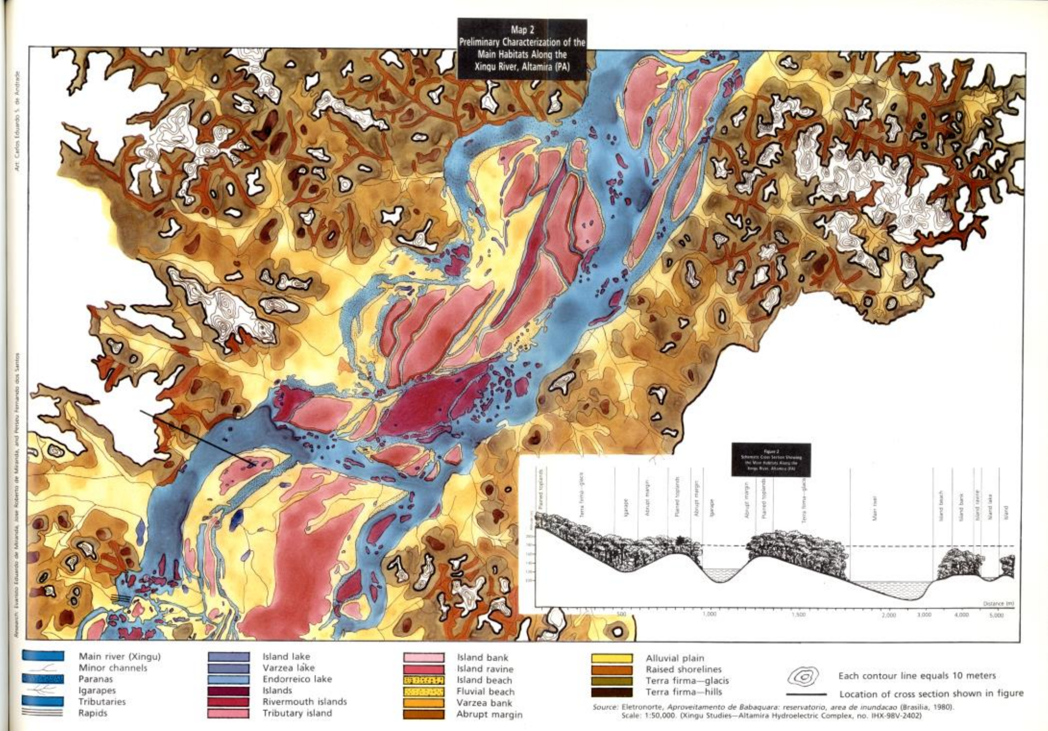
The Planed Toplands

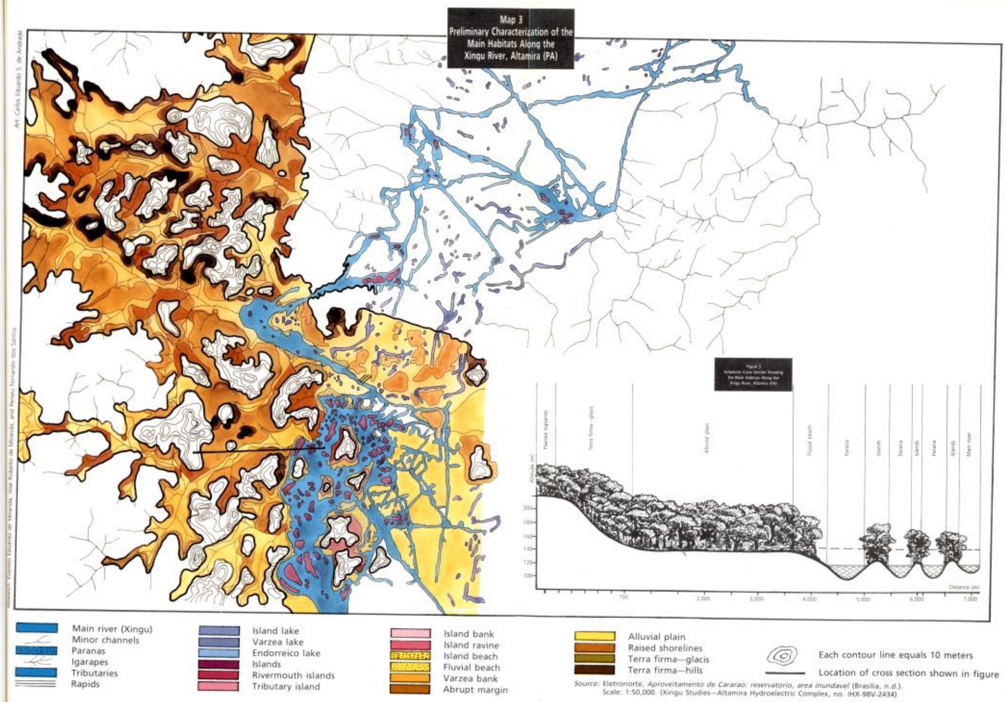
This is a form of residual relief formed by tertiary pediplanation, comprised of tabular surfaces, and corresponding on the top to ancient land surfaces. Planed toplands are maintained by the cementing of sandstones through the interspersing of iron oxides, forming lateritic carapaces responsible for maintaining altitudinal variation. Due to the topographical characteristics of such habitats, the areas corresponding to the flooded area are smaller, and in area 1 represent the loss of 647 hectares. Their generalized occurrence can be seen in Map 2.

The Future Islands

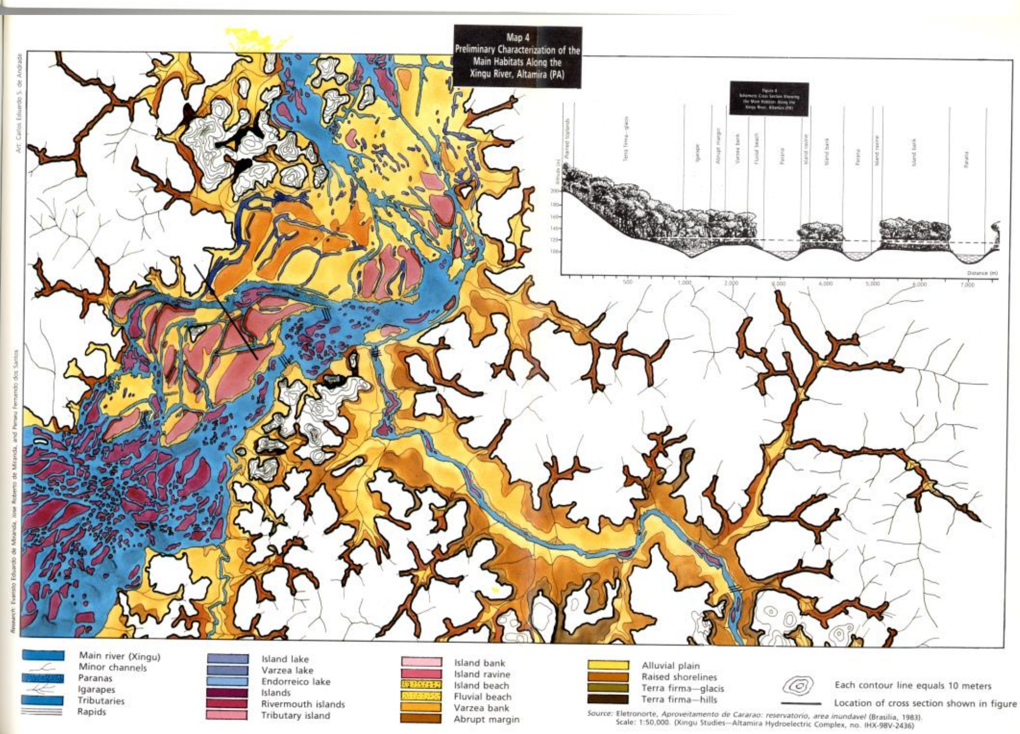
These will be comprised of immersed portions that will present a morpho-genetic slope dynamic with a particular behavior. With the rise in the base level, a large part of the foothill deposits (colluvia, slopes of colluvia, talus) will disappear. The place for the deposit of the sediments removed by surface flow will be the canal itself, with the slope thus being characterized by an environment of removal and translocation of sediments. This could cause morpho-pedological alterations, given that the new dynamic of the slopes will compromise the density of horizon A, by constant removal of organic and clayey material, which could also give rise to processes of intense formation of ravines. Tables 1 and 2 demonstrate the magnitude of the portions of terra firma that will become isolated after flooding, affecting in area 1 6,175 hectares (with a perimeter of 307 km) and in area 2 4,300 hectares (with a perimeter of 197 km). The occurrence of this habitat can be verified on all maps, with an especially notable presence in Maps 2 and 3.□


Map 1
Preliminary Characterization of the Main Habitats Along the Xingu River, Altamira (PA)
Art: Carlos Eduardo S. de Andrade
Main river (Xingu)
Minor channels
Paranas
Igarapes
Tributaries
Rapids
Island lake
Varzea lake
Endorreico lake
Islands
Rivermouth islands
Tributary island
Island bank
Island ravine
Island beach
Fluvial beach
Varzea bank
Abrupt margin
Alluvial plain
Raised shorelines
Terra firma—glacis
Terra firma—hills
Each contour line equals 10 meters
Location of cross section shown in figure
Source: Eletronorte, Aproveitamento de Babaquara: reservatorio, area inundavel (Brasilia, 1980).
Scale: 1:50,000. (Xingu Studies—Altamira Hydroelectric Complex, no. IHX-98V-2400)


Map 2
Preliminary Characterization of the Main Habitats Along the Xingu River, Altamira (PA)
Art: Carlos Eduardo S. de Andrade
Main river (Xingu)
Minor channels
Paranas
Igarapes
Tributaries
Rapids
Island lake
Varzea lake
Endorreico lake
Islands
Rivermouth islands
Tributary island
Island bank
Island ravine
Island beach
Fluvial beach
Varzea bank
Abrupt margin
Alluvial plain
Raised shorelines
Terra firma—glacis
Terra firma—hills
Each contour line equals 10 meters
Location of cross section shown in figure
Source: Eletronorte, Aproveitamento de Babaquara: reservatorio, area de inundacao (Brasilia, 1980).
Scale: 1:50,000. (Xingu Studies—Altamira Hydroelectric Complex, no. IHX-98V-2402)



Source: Eletronorte, *Aproveitamento de Cararao: reservatorio, area inundavel* (Brasilia, n.d.).
Scale: 1:50,000. (Xingu Studies—Altamira Hydroelectric Complex, no. IHX-98V-2434)



Source: Eletronorte, *Aproveitamento de Cararao: reservatorio, area inundavel* (Brasilia, 1983).
Scale: 1:50,000. (Xingu Studies—Altamira Hydroelectric Complex, no. IHX-98V-2436)

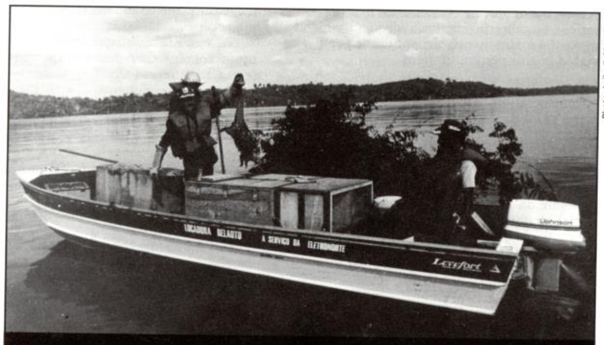


Photo: Leila Jinkings/AGIL

Programs such as "Operation Curupira"—undertaken at the filling of the Tucurui dam reservoir (Tocantins River, PA), with the capture of some species for removal to other areas—do not guarantee that the impacts of the hydroelectric on the fauna will be minimized. Depending on where the animals are taken, this procedure can generate new ecological imbalances.

At the treetop level in terra firma habitats live a large number of birds and mammals. Among these are the common sloth, the royal sloth (*Bradypodidae*), the howler monkeys, and especially the *macaco-pregoes* (*Cebidae*), with a long and prehensile tail, endemic to the Amazon.

While the artificial lakes are filled, when the dams close, the fauna will be more or less affected depending on the average depth of the lakes. In some places the filling will be slow, allowing some species to escape floods. This process necessarily brings about a greater density of faunal populations in the areas where these animals take refuge. Thus, ecological disequilibrium will occur around the reservoirs, widening the direct impact of flooding. At that time, the possibility arises of organizing rescue expeditions for species that are found marooned on treetops or in more elevated regions. The effect of this operation, significant in that it will partially assuage public opinion, will be almost nil with regard to minimizing the ecological impacts. On the contrary, depending on the destination of the animals captured, this strategy could provide a source for new disequilibrium, as in the example of "Operation Curupira."

These brief remarks regarding the areas that will be inundated do not exhaust the question of the ecological impact on the fauna. On the contrary, habitats will be eradicated not only on the level at which they will be submerged by water, but also in the loan areas, used for the construction of dams and numerous containment dikes for lakes; in the removal of wood for the various phases of construction; and in the occupation of areas by worker towns, technicians, and so on. The development of new economic activities will bring more deforestation. Illegal hunting, still limited to the areas near Altamira and along the several water courses today, will increase dramatically.

The qualitative and quantitative loss of terrestrial habitat units on the Xingu River will be significant, and will promote profound changes in the structure of the populations and population areas. These changes must be monitored for early detection of anomalies, indication of areas to be protected, preserved, conserved, and so on (Godron 1979), in the sense of minimizing the ecological impact on the fauna.

To monitor changes in the dynamics of the faunal populations and population areas implies the definition of programs of follow-up research, with allocation of financial, logistical, and human resources to identify the new possible types of equilibria, interactive or not, that will be established among population areas, vertebrate populations, and the habitat (Barbault 1981). For example, it is necessary to detect on the banks of the future reservoirs which places could serve as new egg-laying sites for the aquatic turtle populations (*Podocnemis expansa*). It is necessary to determine the reproductive success of the turtles in these new "reproduction habitats," for they would be insignificant if there were significant predatory pressure on the eggs, the newborns, or the adults. This kind of verification can only come through follow-up studies of these processes. The understanding achieved will provide elements for making conservationist monitoring methods adequate, which will make the maintenance of giant turtle populations viable in this system of dams.

Considerations That Should Be Presented on the Ecological Effects of the Proposed Dams

Preliminary Analysis

A preliminary analysis of the documents available on the section of the Xingu permits an initial definition of the nature of the studies necessary to evaluate and compare the ecological repercussions of the system of dams as currently proposed, within the methodological framework previously used.

The drainage area of approximately 510,000 km² covers a great variety of ecological situations defined at the macro-regional level by the existing north-south climatic gradient. Interacting with this larger conditioning factor is the diversity of the physical environment crossed by the Xingu, where several geological, geomorphological, lithological, and pedological structures form the locus of a extremely variable human occupation and use pattern. This diversity ranges from urban centers such as Altamira to indigenous villages. Thus, the actual structure of the flora and vegetation, the faunal populations, and the population areas should be studied at the ecological system level. The characterization of the ecological systems that will be flooded or altered by the dams should be executed in the most specific manner possible.

In this sense, the work to be done should present three levels of results:

(a) the probable effects of the dams on the principal ecosystems or habitats of the region;

(b) the probable effects of the dams on the actual floral and faunal resources of the region;

(c) a synthesis, by dam, subsystem of dams, and for the proposed system as a whole, of the probable effects of the process of implantation, installation, and management of the reservoirs.

These three complementary studies would, for example, make viable an evaluation and comparison of ecological recovery for the different alternatives for fall division, energy development, hydrological management of the dams, tracing of the transmission line, localization of the work areas, worker residential units, loan areas, and so on.

Finally, this study should also contain a chapter indicating proposals for the ecological monitoring of the area. A zoning of the Xingu Basin must be presented, indicating the areas destined for utilization, preservation, conservation, and protection for the ecological systems considered. Each one of these four concepts requires specific planning and monitoring strategies. Only with these elements will Brazilian society, with the participation of the scientific community, be able to comprehend and judge the positive and negative dimensions of this project.

The rest of this chapter will present the minimum content that can be expected of the final report with regard to:

(a) ecological systems;

(b) flora and vegetation;

(c) faunal populations and population areas;

(d) synthesis at different levels of the system of dams;

(e) action proposals for monitoring future ecological administration of the system of dams in the Xingu Basin.

The Study of the Xingu Basin's Ecological Systems

There are currently a series of internationally developed methods and techniques that permit short-term detection, identification, qualification, and quantification of the region's ecological systems. This initial inventory and evaluation should be undertaken in a semi-detailed way in the areas flooded and areas adjacent to the dams, and in an exploratory way in the area of the basin between parallels 5 and 12 as a whole. In the first level of study, the work should be executed in relatively large scales (1:50,000 to 1:100,000), and on the second level on medium scales (1:250,000 to 1:500,000).

The preliminary work done thus far shows the existence of about 40 distinct environments or habitats that will be directly altered by the construction of the dams, just in the immediate areas of the two locales studied on the Xingu and its tributaries. A hierarchized legend of these habitats and of their future ecological perspective with the construction of the dams has already been prepared and could serve as the basis for a future photo-interpretation. A preliminary cartographic outline for a later one-site field reconnaissance, which also has already been done (on the scale of 1:50,000), could be generalized with more details for the entire area by those responsible for the project.

When preparing the final report—with objective data that might permit the definition of options for those responsible in terms of the implementation of the dams—various internationally utilized ecological indices should be calculated to quantify the effects of the two levels of flooding actually proposed. The results should be represented numerically, graphically, and cartographically, distributed to multi-disciplinary teams, and made comprehensible to anyone interested in this project.

The Study of the Xingu Basin's Flora and Vegetation

In Amazonia, it has been common to present floral inventories as a basis for evaluating the ecological effects of dam construction. These studies are frequently prepared on the basis of general bibliographical compilations, and do not offer a mapped representation of their results. It is not uncommon to see a confusion of concepts and definitions in the description of the flora and vegetation, and yet from this information an evaluation of ecological effects is expected to emerge. With the data currently available on the region, it could be affirmed, with great probability of accuracy, that there will be practically no significant alterations in the region's flora. However, the probable changes at the vegetation level will be of great magnitude. Thus, it is sufficient to point out that, even running the risk of a tautology, the flora represent the list of plants that grow in a given place. All those of the same species are designated by the same specific name, and all species are treated on the same plane (the common and the rare, the small and the large). The flora result from ancient actions and translate a whole botanical history. This is particularly important in regions such as the Xingu Basin—above all in its southern part—given the climatic fluctuations that occurred during the Quaternary era.

Vegetation, on the other hand, is the organized spatial emergence of the flora in interaction with a region's physical conditions. In this sense, the vegetation is comprised of the complex set of plants (frequently considered vasculars) that grow in a given place. The vegetation always represents a current datum, sensitive to variations as a function of the human presence in the area and of other factors. When compared with the flora, it is a very dynamic dimension. The different floral species fill diverse roles depending on their importance in terms of effective size and functions. The preliminary study of the vegetation of the Xingu River Basin, and principally of the areas that will be flooded, shows that this is comprised of complex wholes or very variable, and varied, vegetal communities from one place to another. These communities represent diversified uses for the fauna and for humans, above all the indigenous populations.

To evaluate the ecological effect of the dams on the flora and vegetation, it seems pertinent, at the level of inventory, to consider vegetal formations, forms of vegetation, the dominant species and their diverse functions (production, protection of soils, hunting, etc.). This study implies a more detailed preliminary cartographic analysis (1:100,000), based on aerial photography (1:40,000) and field surveys. The maps should simultaneously contain the habitat and vegetation units on the scale of 1:100,000, as well as their respective planimetry.

The actual use of lands should be mapped and translated into indices and rates of occupation; the degree of artificialization, measured by the greater or lesser influence of humans on the vegetation and physical surroundings, analyzed for the whole of the basin; the variables which interfere in the actual phytodynamics identified and described in a succinct manner. Indications on unconsidered aspects in terms of phytodynamics, which will occur between the upstream and downstream areas of determined dams in the proposed system, should be presented. The first study already provides good indications for critical areas in terms of utilization and preservation. This complementary study of the area's vegetation will provide specific indications as to the portions of territory that should be protected and conserved. The nature of these actions and the strategy adequate for their planning, implantation, and future monitoring should also be indicated in their main lines in the report, as a basis for future decision and a guarantee of their clarity for the public and national and international scientific community.

The Study of the Xingu Basin's Faunal Populations and Population Areas

Frequently, considerations of the ecological effects that dams have on animal communities aim to give a repertoire of the principal species present. This being the case, they undertake a faunal inventory of the principal populations found in a given area. This kind of purely qualitative survey does not take into account the principal relations existing between the faunal populations and different ecological situations. Since the structure of the habitat and food resources available in each type of "surrounding" conditions the presence of distinct faunal populations, it is fundamental to give an ecological direction to the analysis of fauna, as much in terms of populations as population areas.

The faunal population areas can be considered as an assemblage of species sensitive to the same biotic and abiotic factors of the physical surrounding. It is these factors that impose a distinctive character on each one of the population areas of a biocenosis. Ecologists today utilize statistical-mathematical methods for detecting, qualifying, and hierarchizing these ecological factors. Faunal population areas correspond to the level of perception of the biotopes. They present a greater or lesser number of species (specific richness), depending on the natural resources offered by the biotopes and on the level of specialization of the species that comprise them. In this sense, they should be considered as a point of departure in the evaluation of the ecological effects of the dams, above all in the case in question. In fact, the Xingu Basin corresponds to an important area of transition between the very distinct faunal and ecological domains of central Brazil and Amazonia.

Not all species perform equal roles at the level of faunal population areas. Some areas have species of ubiquitous tendency, very frequent and of great ecological tolerance, for they are present in almost all types of "surroundings." Other faunal population areas are comprised of specialized species, characteristic of determined "surroundings" where certain ecological conditions hold. These interactions among the principal kinds of "surroundings" and the large faunal population areas must be considered, even if in a preliminary way, in the ecological inventory of the Xingu Basin fauna. Several rigorous scientific methods permit an initial evaluation of this dimension, providing elements to evaluate the probable ecological effects of the system of proposed dams on the region's fauna.

Photo: William Fisher

On the banks of the Bacaja River, Kayapo-Xikrin Indians prepare to transport castanha nuts.

The ecological effects on the faunal population areas of the project in question have to be evaluated in the complex whole of the Xingu sub-basins. It is important to determine the ecological microfactors that condition the spatial distribution of the main population areas and faunal biotopes. Field work should offer a more precise characterization of these biotopes. It is important to present a list of the populations existing in the area, with a succinct commentary on the ecology of the principal species and their future evolutionary tendency following the implementation of the program of dams on the middle Xingu. In a complementary fashion, a preliminary evaluation of the most characteristic faunal population areas for the main biotopes and the functional nature of their relations (locations of reproduction, food, ecotopes that perform a role as refuge areas for particular population areas, etc.) should be offered.

In an initial analysis of these major types of biotopes and population areas, it is sufficient to quantify them as to their specific richness (total and average) and their respective ecological complexities. These can be measured through the different internationally utilized indices of diversity (H'alfa = intra-biotope diversity; H'gamma = diversity of the number of ecological niches realized; H'beta = index of inter-biotope similarity). These algorithms are practical and objective instruments for characterizing and evaluating the ecological complexity of different types of biotopes and faunal population areas. Thus, for certain rare biotopes with complex faunal population areas that will be reduced by dam construction, these indices of diversity can provide indications and precise directions on places that should be protected and conserved. In an analogous way, various biotopes should increase significantly with the construction of the dams, and these consequences need to be measured.

Finally, it is necessary to indicate the indices of ecological diversity that should be utilized in monitoring the populations, the faunal population areas, and their respective biotopes with the aim to protect, preserve, and conserve them in the future.

Preliminary Synthesis of the Proposed Ecological Effects by Dam, Dam Subsystem, and Total System in the Xingu Basin

Despite the scenarios that exist for implanting the system of dams, it is important to present a synthesis according to the most probable main alternative. Thus, the synthesis should consider each dam. For each case, a synthetic dossier must summarize the essential aspects of the ecological, floral-vegetational, and zooecological studies, presenting in the form of tables the essential numerical and cartographic information obtained in the afferent studies. The synthesis by dam subsystems should be organized according to the ecological significance of the data obtained in the preceding stages. It is not possible to define a pirori what these subsystems would be, but they will represent homogeneous wholes in terms of problems of ecological effects and planning strategy. At the level of the system to be implanted as a whole, it is important to consolidate the preceding stages; this will permit a global vision of the problems related to the process of implantation of the reservoirs and their probable effects on the environment and the anticipated projects.

It should be taken into consideration that the projects for construction of hydroelectrics, through the formation of reservoirs, generally result in new access routes to the areas upriver in the hydrographic basin; this also has impacts on the forest, wildlife, exploitation of mineral deposits, and agricultural practices in this same basin.

Proposals for Planning the Monitoring and Future Ecological Administration of the Xingu Basin

Given the developmentalist character of the Xingu dams, principally benefiting mining projects in their immediate surroundings, the assessment of the ecological impacts of this undertaking should present a balance between the quantity of units of value for habitats lost and gained, as much with the area flooded as with the drastic changes that may occur in the pattern of flow and quality of water, in the reservoir area and in the river system downriver. It should also present a detailed mapping of the units that will have to be monitored and improved with the new situation following the implantation of the project.

It is urgent that elements be proposed for a future monitoring and a possible global evaluation of the impacts of the Xingu dams on the ecological resources. An indication of the possible topics to be considered is provided here, considering the ecological effects of the dams in preliminary terms.

Fisheries Productivity

1. Loss of production should be evaluated, before the project is begun, on the fish existing in the riverine system. These losses can be caused by the reduction of areas flooded downstream, by the decrease in the production of fish in the zone of the rivers below the dam where the change in hydrology will be greater. Also, the reduction of nutrients downriver result when the dam interferes with fishing activity, as well as with migratory species.

2. The new situation of fishing in the reservoir should be outlined, including plans for managing the fish populations and also the expected effects on the fishing situation of the rivers that will be altered, especially in the lacunary zones downriver. The evolution of the submerged vegetal mass and its ecological consequences also must be considered and evaluated.

3. A comparison of the new situation to the old and a description of the plans for managing the replacement of lost fishery biomass is a minimum requirement on this topic.

Aquatic Ecosystems

1. First, the expected situation in the reservoir should be described, anticipating changes in the physical, chemical, and biological properties, including the water column and bentonic region.

2. The effects on the affected lacunary and waterlogged zones must be evaluated, including changes in salinity, probable effects of primary productivity of the food chains, considering as much the biological life of the water column and the bentonic region. Monitoring programs to evaluate conditions must be outlined before and after the dams in order to establish basic data. These will be utilized, if necessary, in planning corrective measures, including sampling details, and physical, chemical, and biological analyses of the aquatic zones affected; the frequency of sampling needed to give statistically valid information for all seasons of the year; as well as describing a priori the analytical methods for interpreting the significance of the data and the access that civil society will have to these works and results.

3. The monitoring of the management program for aquatic ecosystems should be part of the project's operationalization. It must be delineated for a continuous evaluation that can be done over the years, measuring the effect of the project on the modification of aquatic ecosystems. To describe viable corrective measures when required is also an important component (fish runs, artificial beaches for reptilian egg-laying, etc.)

Terrestrial Fauna

1. The impact of the project on the wildlife in the hydrographic basin above the reservoir and also in the downriver zones affected by the change in the hydrological regimes, and by changes in the access routes to the basin, must be described, including as much the region of the reservoir as the roads and infrastructures that will be constructed.

2. The impact on the fauna that will be inundated and plans for the rehabilitation and rescue of the same should be presented with indication of who will execute them and how they will be executed.

3. The new natural resource (wildlife) that will be formed by the reservoir and plans for its manage-

ment should be detailed. Specifically, for some regions, schemes should be presented to guarantee the conservation and protection of the population and population areas most affected.

4. The plan and resources necessary for the establishment of wildlife reserves in the hydrographic basin must be presented in detail as an integral part of the planning of the project (as a way of compensating for the losses of wildlife created by the same) and details should be supplied on how resources will be allocated and administered (Godron 1979).

Terrestrial Ecosystems

The impact of the projects on the flooded ecosystems should be foreseen, including:

1. the estimated loss of primary productivity of the forests and other terrestrial ecosystems;
2. the accelerated depreciation of these ecosystems increased by the new access routes as much by the new lake so created as by the new roads and infrastructures that will be built;
3. the present and future status of the forests in the hydrographic basin and their role in the conservation of water and of the soil; and
4. the measures proposed for preserving the role of these ecosystems in the hydrographic basin and the future rehabilitation of the loan areas, work areas, and so on.

Formation of the Reservoir

The environment of the new reservoir should be described ahead of time, including:

1. the new potential for fishing to be created and the plans for its administration, including the management of fish communities and regulations for the exploitation, commercialization, and storage of fish and fish products;
2. the use of the reservoir for the propagation of wildlife and for scientific research;
3. the physical, chemical, and biological properties of the new body of water, including the column of water and the bentonic region—for example, phenomena of thermic stratification and others that could occur;
4. the problem of stability of embankments and dikes, including protection against erosion created by wave action and preventive measures against possible breaks (above all in the numerous containment dikes found in the project);
5. sanitary control on the periphery of the new reservoir;
6. the systematic, systemic, and effective regulation of the use of upstream and downstream areas for agriculture and other purposes (Spedding 1979);
7. the ecological problems created by fluctuating levels of surface waters should be researched;
8. whether the trees that will be flooded will be removed or maintained and how their genetic preservation will be accomplished;
9. the problems for monitoring and controlling the growth of aquatic plants in the reservoirs; and
10. other problems related to the reservoir and that are not normally discussed in the Environmental Impact Report.

Conclusions

The relations between ecology and development are tragically difficult in Brazil. Economic and social imperatives have led those responsible to see in ecologists perennial censors of their actions. Ecologists in turn look on development projects with extreme distrust, for, in these cases, there exists a tradition of crimes against the environment, reinforced by impunity. It is urgent that a dialogue of trust be reestablished; this does not mean agreement between ecology and development at the level of the projects, above all when they reach the magnitude of the system of dams proposed for the Xingu.

The direct ecological impact of the proposed system of dams will be enormous, certainly the largest that the country has known. It is not limited to the artificial lake that will be created, the consequences of which in terms of the disappearing habitats have been preliminarily considered here. Despite its limited character, this small study of habitats in this chapter illustrates the diversity of ecological situations and the need for an assessment of the dams' impacts within internationally recognized, qualitative, numerical, and cartographic parameters. The considerable number of containment dikes, the dams themselves, the areas that supply earth and material for construction, the roads, the installation of work areas, residential units for technicians and workers, the building of transmission lines—all are among the main direct ecological impacts of this undertaking. In this sense, this ecological impact analysis is but a pale reflection of what the direct alterations promoted by the project are, should it come to be realized. These losses in natural resources are losses not only for the present but also for the future; it is an irremediably lost potential with no future perspective. But there also exist indirect and differentiated ecological impacts in time. These will be more serious. They are connected to the predatory and speculative economic development familiar to the region of legal Amazonia: extension of nonproductive pastures; indiscriminate deforestation; opening of roads, mines, and mining areas; disorderly growth of cities and towns; increases in illegal hunting and illegal exploitation of lumber and forest species; invasion of forest reserves and indigenous territories, and so on.

THE COUNTRY NO LONGER ACCEPTS development at any price; it wants to know what impacts the project will have, who its beneficiaries will be, who it will hurt, and who it is paying. Moreover, the country wants to decide and to be heard. In the case of hydroelectrics, this question has demanded an increasing effort on the part of companies that generate and distribute energy to "manage the interferences connected to the environment." The case of the Xingu River will perhaps represent the occasion for overcoming determined conflicts and historic distrust, to the extent that these questions are duly considered. There are excellent examples, at the international level, even in underdeveloped countries, for Brazil to consider. In this sense, it is not enough to comply with the law. It is not enough to present the RIMA. The dimension of the work, the ecological characteristics of the region, and the direct and indirect impacts of the proposed project demand a wider evaluation on the part of the government and proponent agencies. In the framework of current legislation, the RIMA, even if it is prepared, would be insufficient to deal satisfactorily with all the factors involved in this question. It is up to the public authorities and to the proponents to take the initiative to overcome the narrowness of current legislation and the studies presented up until now. It is not by hiring some consultants, however competent they may be, that all ecological questions inherent to the dams and reservoirs to be created on the Xingu will be answered.

The new Constitution will create pertinent mechanisms to assess and decide on the need for this and other large works. If confirmed, the measures necessary to evaluate their ecological impacts will have to consider the reflections of the scientific community and those portions of society concerned with preserving nature. These sectors are mobilized and vigilant. Certainly they will intervene in an unprecedented way in this case. Several elements about the report that should be presented, dealing with the direct and indirect ecological effects of the Xingu dams, were considered in this chapter by way of collaboration. In its present form, a simple RIMA is not enough.

The problem of the Xingu dams will surpass the ecological question, creating a crisis of much more serious dimensions. In the face of the current legislation, whoever wants to defend the legitimacy of such an undertaking will have to opt for the way of illegality.

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