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Limnological and ecological methods: approaches, and sampling strategies for middle Xingu River in the area of influence of future Belo Monte Power Plant

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(With 7 figures)

Abstract

In this paper the authors describe the limnological approaches, the sampling methodology, and strategy adopted in the study of the Xingu River in the area of influence of future Belo Monte Power Plant. The river ecosystems are characterized by unidirectional current, highly variable in time depending on the climatic situation the drainage pattern an hydrological cycle. Continuous vertical mixing with currents and turbulence, are characteristic of these ecosystems. All these basic mechanisms were taken into consideration in the sampling strategy and field work carried out in the Xingu River Basin, upstream and downstream the future Belo Monte Power Plant Units.

Keywords: limnology, sampling strategies, Xingu River, ecosystem, rivers, Belo Monte Power Plant.

Estudo limnológico e da biota aquática no Rio Xingu na área de influência de UHE Belo Monte: metodologia e abordagens

Resumo

Neste trabalho os autores descrevem as abordagens limnológicas e a metodologia e estratégia de amostragem adotadas no estudo do Rio Xingu, na área de influência da futura Usina da Belo Monte (UHE Belo Monte). O ecossistema de rios é caracterizado por velocidade unidirecional de correntes, muitas flutuações de fluxos dependendo do clima do padrão de drenagem e do ciclo hidrológico. Mistura vertical permanente e turbulências ocorrem constantemente devido a correntes predominantes. Todos estes mecanismos gerais e específicos característicos do Rio Xingu, foram levados em consideração no plano de estudos limnológicos e amostragens desenvolvidas na área de influência de UHE Belo Monte a montante e a jusante do futuro empreendimento.

Palavras-chave: limnologia, estratégias de amostragem, Rio Xingu, ecossistemas, rios, UHE Belo Monte.

1. Introduction

The operations involved in limnological studies and water quality assessments, are several and complex. They have a series of links and the failure in any one of these can weaken the whole assessment and produce wrong information. Limnology of rivers are fundamental as a information system in order to evaluate the state of a water body (Tundisi and Matsumura-Tundisi, 2008, 2012).

Furthermore limnological studies and water quality assessments are essential in the design of strategies for future management and follow up of reservoir construction (Tundisi and Straskraba, 1999).

In order to produce comprehensive limnological studies and water quality assessments that are useful to decision makers, the design of the sampling strategies must take into account the precise objectives of the project, its impacts and future developments (Chapman, 1992).

Limnology of rivers and water quality assessments, must therefore be considered as an information system, of present and future status of freshwater ecosystems subjected to impacts such as reservoir construction (Straskraba and Tundisi, 2000). The use of the monitoring has evolved, from mere diagnosis to determine and advance trends in the quality of freshwater ecosystems, and how they are affected by the anthropogenic activities.

In the Amazon Watershed,intensive limnological and water quality studies are even more important due to its complexity of the ecological dynamics (Barrow, 1983; Tundisi and Straskraba, 1999; Tundisi and Matsumura-Tundisi, 2013a). The construction and operation of reservoirs in this region depends upon the monitoring and impact assessment before, during construction, and after the reservoir is completed.

2. Rivers as Ecosystems

A river differs from other freshwater ecosystems, in two fundamental ways: first the permanent horizontal movement of a river current – unidirectional – and the second is the interaction with its drainage basin, from which a permanent contribution of allocthonous material arises – mainly components of vegetation remains such as leaves, fruits, roots, and erosive materials from the soils. The water motion in the river controls the structure of the bottom and the materials found in the sediment. Fluvial geomorphology determines, the main characteristics of the tributaries. Physical factors, affecting the transport of matter and load include: width, depth of the river channel, the velocity of the flow, the degree of roughness of the sediment, the degree of sinuosity of the river and its major tributaries (Allan, 1995). Rivers are transport systems for particulate and dissolved organic and inorganic matter, for insect larvae, remains of organisms, fish eggs, aquatic plants (Whiton, 1975; Tundisi and Matsumura-Tundisi, 2008, 2013a). The dominant invertebrates in the river are benthic, the dominant vertebrates are fish (Margalef, 1993).

River hydraulics influences the distribution of sediments in the bottom and of the benthic macroinvertebrates (Bettler et al., 2014; Amsler et al., 2009). Large rivers of the Amazon Basin have special features as regards morphometry, volume, seasonal changes in discharge and chemical composition of the water. (Sioli, 1984).

Therefore sampling strategies and environmental impact assessment of this freshwater ecosystem have to take into account these special features.

3. The Xingu River Watershed

The Xingu River watershed is located on the right margin of the Amazon River and occupies an area of 520.292 km^2 (Figure 1). The Xingu River has its headwaters in the region of the brazilian shield and flows north to discharge in the Amazon River. As classified by Sioli (1975) the Xingu River is a clear water river, with transparency higher than the white water rivers, pH between 6.0-7.0, well oxygenate waters and low ionic concentration.

The river has a complex morphometry specially near the Amazon River and in the site where it is located the future Belo Monte Power Plant (Figure 2).

One of the main characteristics of this river, is that it has innumerous tributaries. The connection of these tributaries with the main river is a fundamental ecological process that maintain the flux of organic matter to the Xingu River and acts as the marginal lakes as a capacitor of biomass to the main river. The basin is occupied with 25% of cropland, and has a forest cover of 70% (Revenga et al., 1998)

4. Methodological Approaches and Strategies

Since the determination of limnological variables and water quality assessments are fundamental to analyze present and future impacts and trends the following strategies were part of the design for the spatial and temporal sampling:

- To analyze the adequacy of the water quality to the proposed future multiple uses in the area of influence of the Power Plant, during the construction, filling and operation phase, of the reservoirs.
- To provide precise information to support management of the watershed and water bodies (river, tributaries, reservoirs).
- To provide information on the impact of the construction of Belo Monte Power Plant on the water quality and aquatic biota during the various stages of the construction, filling and operation.
- To provide limnological information to support the mathematical modeling project of the water quality prognosis of the Xingu reservoir, middle reservoir and downstream the Power Plant.
- To promote an interface with the Environmental Plan of Construction; the program of the monitoring of the aquatic Macrophytes; the conservation of fishes species; the Public Health program; the Social Communication plan and the Environmental Education, projects.
- Classification of waters for water uses, followed CONAMA 357/2005 (Brasil, 2005); and CONAMA 454/2012 (Brasil, 2012) for sediment classification was followed.

4.1. Selection of sampling sites

The selection of the monitoring stations for assessment of water quality and limnological studies, sediment composition and aquatic biota was based on the results of the Environmental Impact Assessment of 2007, field surveillance, in accordance with IBAMA (2013) and North Energy technical regulations. CONAMA 357 environmental regulation for water quality was followed during all stages of the sampling, field and laboratory work.

Criteria adopted for the selection of sampling sites and sampling stations were based on the impact of the construction work: urban areas, suppression of vegetation, villages, access roads, construction support areas, transmission lines.

4.2. Temporal strategy of sampling

Due to the dynamics of the river ecosystem and its response to the interactions climate/hydrology, sampling strategies have to consider the temporal dynamics of the system (represented mainly by the fluvial dynamics) during periods of high water and low water (Tundisi et al., 2008; Martinelli et al., 2012; Agostinho et al., 2009) (Figure 3).

Sampling strategies involved three periods depending on the intensity of the construction work and the need to

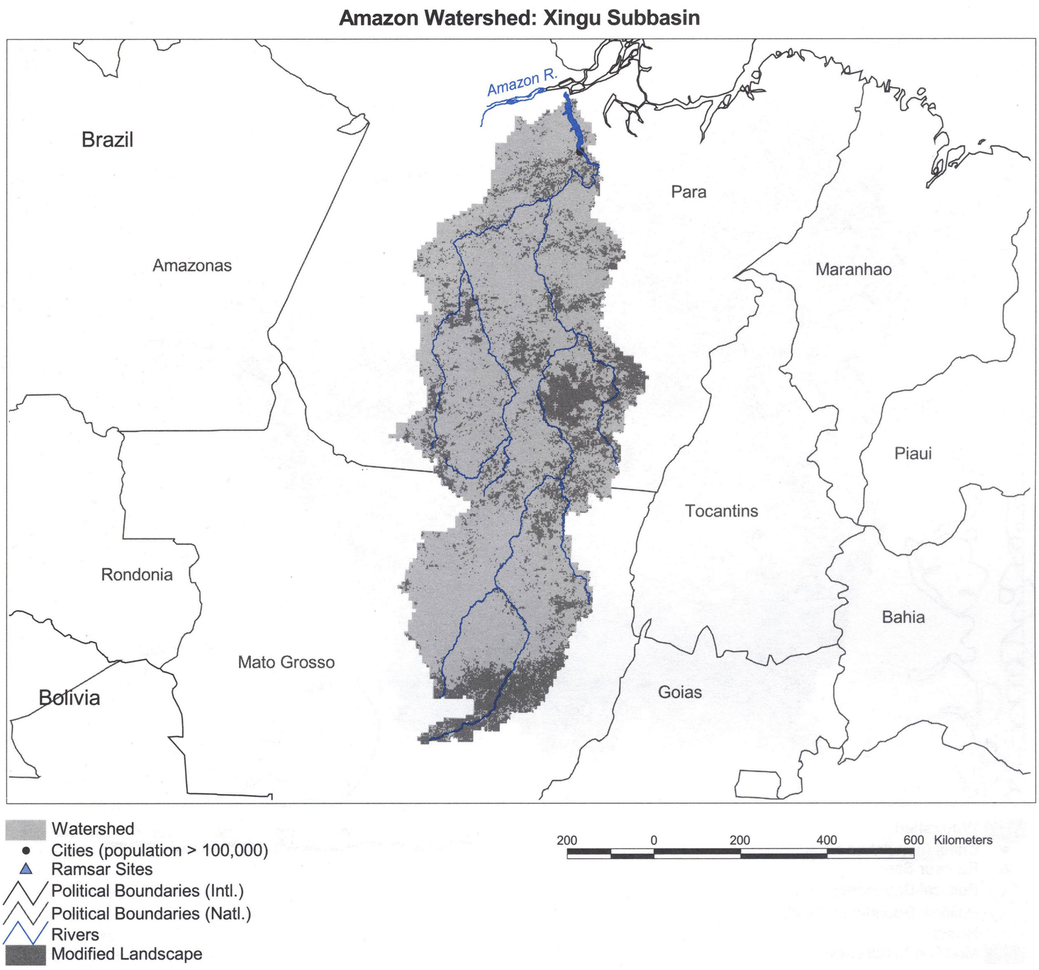

Figure 1. The Xingu River Basin (Revenga et al. 1998).

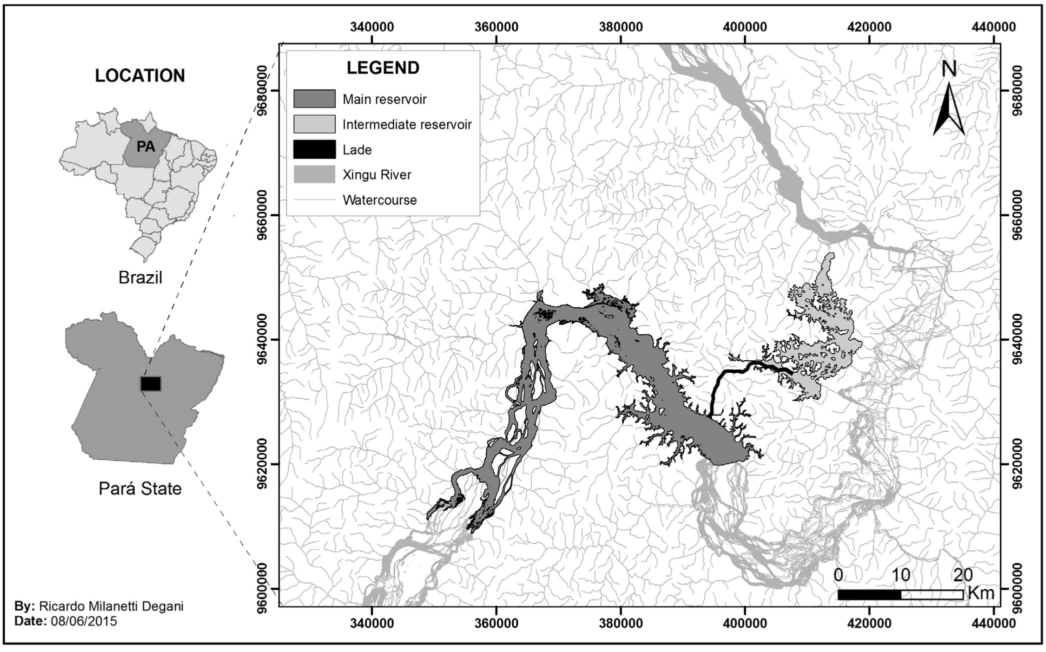

Figure 2. The complex morfometry of Xingu River and its tributaries.

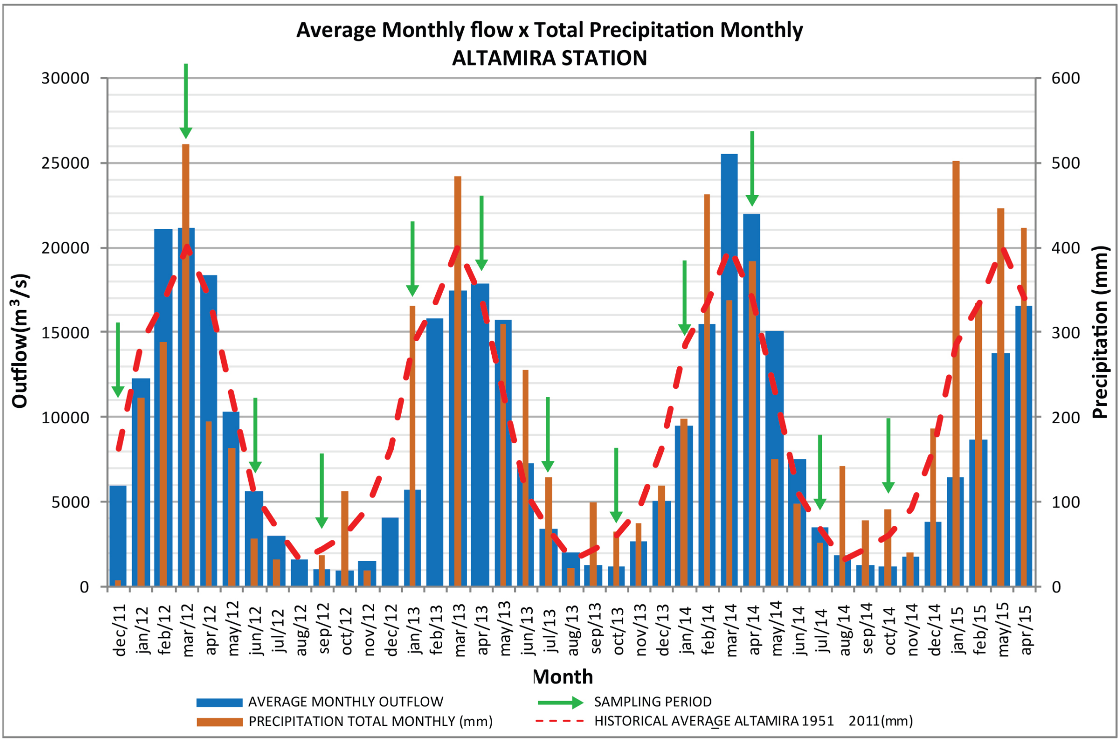

Figure 3. Temporal dynamiscs of the hydrological cycle and the sampling periods.

detect changes in water quality: monthly sampling near the construction site and the transmission lines; weekly sampling upstream and downstream the main reservoir in the Xingu River; general sampling every three months; this was distributed along the Xingu River and tributaries, upstream the main reservoir in the Xingu River, region of reduced flux and downstream the Power Plant. Number of stations: monthly sampling 32 stations; weekly sampling 7 stations; sampling every three months: 35 stations. Figures 4, 5, 6 and 7, shows the sampling stations and their distribution in the river, tributaries and construction sites. Table 1 shows the details of the methods used with references and a brief description of methodology.

Tables 1A, 2A, 3A and 4A (see Annex A) describe the location of the sampling sites with the geographic coordinates.

5. Limnological Surveys and Water Quality Assessments

5.1. General approach

Any information system based on limnological surveys and water quality must take into account all the physical, chemical and biological components of the river ecosystem. Since rivers are dynamic systems that respond to the physical characteristics of the watershed and are controlled by local and regional geological and climatic conditions, it is necessary to include all the components of the ecosystem in order to understand seasonal variation and all man, induced changes in the aquatic biota that once identified can be used to follow and monitor charges in the river environment. The complexity and components of the assessment programs are defined by the future water uses, the water quality requirements and the determination of the impacts produced by the Power Plant construction (Chapman, 1992; Tundisi and Straskraba, 1999).

5.2. Multipurpose river quality monitoring programme

5.2.1. Sampling methods abiotic parameters

Sampling of the physical and some chemical parameters was carried out with submersible probes with multiparametric sensors. In situ sampling of water temperature (°C); pH; dissolved oxygen (mgxl^{-1}), conductivity (µS x cm^{-1}); turbidity (NT units); redox potential and total dissolved solids was carried out routinely in weekly, monthly or every three months periods. Sampling for other chemical variables such as total phosphorus, inorganic phosphate, nitrite, ammonium, nitrate were collected at surface with plastic non toxic bottles, frozen, and analyzed by spectrophotometric or liquid chromatography. Metals were analyzed by atomic absorption spectrophotometry. They were: Aluminum, Copper, Cadmium; Chromium; Lead; total Iron; dissolved Iron; Zinc; Manganese, Magnesium; Arsenium; Mercury and Selenium. Ionic composition of water: Potassium; Sodium; Magnesium; Chloride; Sulphate, Bromium, Fluoride.

Biochemical oxygen demand (DBO 5 20), total suspended material (organic and inorganic) pesticides and herbicides completed the analysis of the abiotic factors.

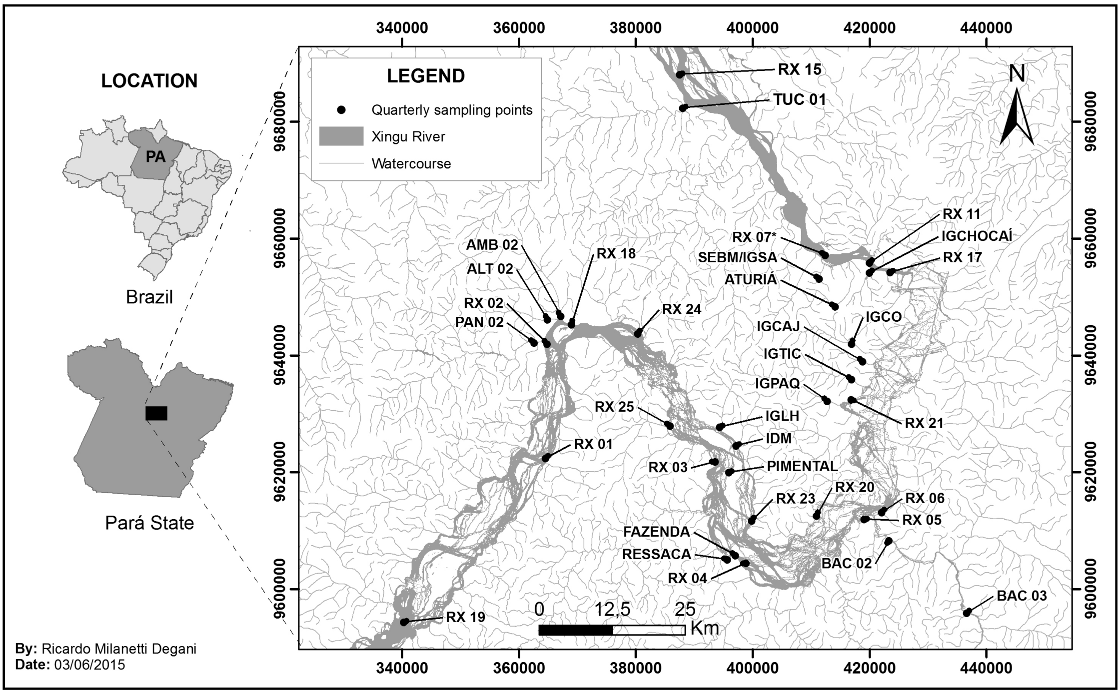

Figure 4. The geographical distribution of the quarterly sampling points.

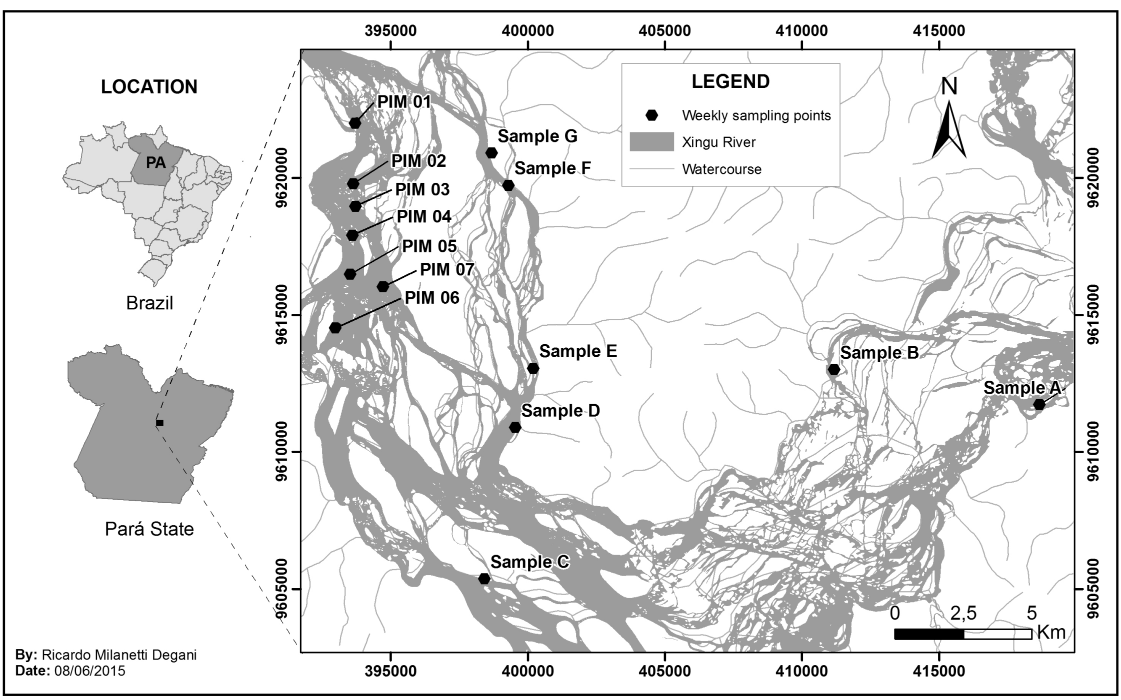

Figure 5. The geographical distribution of the weekly sampling stations.

5.2.2. Sampling methods for sediment analysis

Sediment analysis was performed in the laboratory after collecting samples with special equipment: Eckman Birge Sample or plastic spatulas. Sample were frozen before analysis; chemical analysis were carried out for total nitrogen, total phosphorus, particulate carbon (organic and inorganic) and metals: Aluminium, Cooper; Cadmium, Lead, Cromium, total Iron; dissolved iron; Zinc, Manganese, Magnesium, Arsenium, Mercury and Selenium. A granulometric analysis of the sediment was carried out simultaneously (Munawar, 2003).

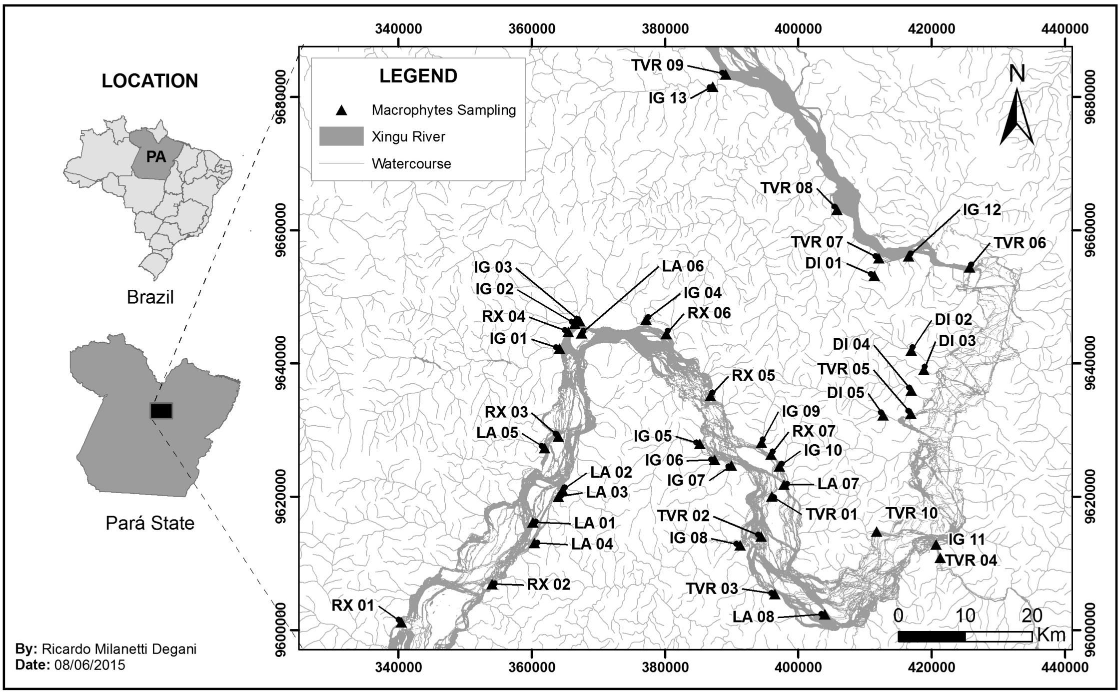

Figure 6. The geographical distribution of macrophyte sampling.

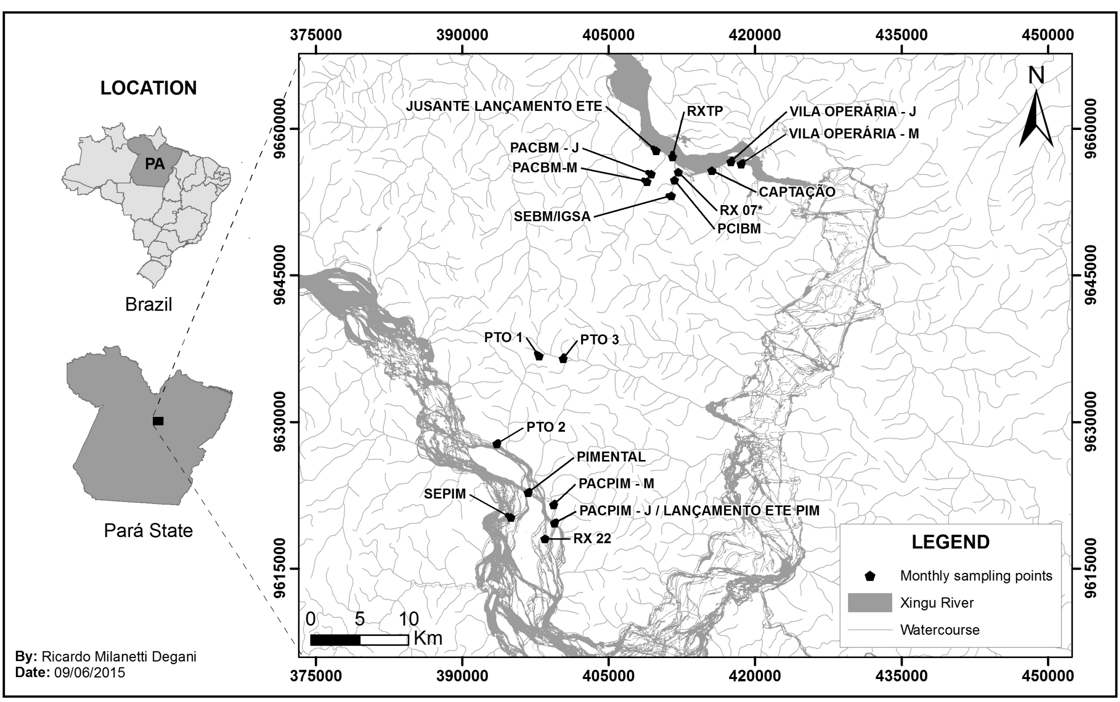

Figure 7. The geographical distribution of the monthly sampling points.

5.2.3. Biological assessments

Most organisms of the aquatic biota are sensitive to changes in the environment, due to natural causes (changes in flow, turbidity, consequences of heavy rainfall) or manmade impacts such as pollution and discharge of contaminants or remains of construction works, or other effects on the water quality or on the physical structure of rivers. Different organisms respond to in different ways: mass death; migration; changes in metabolism; changes in number of species; extinction. The study of organisms "in situ" can produce a series of informations on water quality about impacts. Sampling with standardized methods and

Table 1. Physical, chemical and biological variables monitored and the analytical methods utilized on the sampling strategy at Xingu River.

SURFACE WATER			
VARIABLES	**UNITY**	**METHOD**	**BASIC REFERENCES**
Depth	m	Depth Measurer	Speedtech Instruments
pH	pH units	Multiparametric sensors	YSI Incorporated
Electrical Conductivity	µS/cm	Multiparametric sensors	YSI Incorporated
Turbidity	UNT	Multiparametric sensors	YSI Incorporated
Dissolved Oxygen	mg/L	Multiparametric sensors	YSI Incorporated
Saturation of D.O.	%	Multiparametric sensors	YSI Incorporated
Water Temp.	°C	Multiparametric sensors	YSI Incorporated
Total Suspended Solids	mg/L	Multiparametric sensors	YSI Incorporated
Redox Potential	mV	Multiparametric sensors	YSI Incorporated
Transparency	m	Secchi Disk	Wetzel and Likens (1991)
Apparent color	mg PtCo/L	Spectrophotometry	APHA et al. (1998)
True color	mg PtCo/L	Spectrophotometry	APHA et al. (1998)
Suspended Organic Matter	mg/L	Gravimetry	Wetzel and Likens (1991)
Alkalinity	mg-$CaCO_3$/L	Titrimetry with H_2SO_4	APHA et al. (1998)
$BOD_{5,20}$	mg/L	Incubation & Titration (Winkler)	APHA et al. (1998)
Total Phosphorus	µg-P/L	Colorimetric Method Spectrophotometry	Valderrama (1981)
Total Nitrogen Kjeldhall	mg-NTK/L	Acid Digestion	APHA et al. (1998)
Nitrite	µg-N/L	Liquid Chromatography	APHA et al. (1998)
Nitrite	µg-N/L	Liquid Chromatography	APHA et al. (1998)
Amonium	µg-N/L	Liquid Chromatography	APHA et al. (1998)
Fluoride	µg/L	Liquid Chromatography	APHA et al. (1998)
Cloride	mg/L	Liquid Chromatography	APHA et al. (1998)
Bromide	µg/L	Liquid Chromatography	APHA et al. (1998)
Lithium	µg/L	Liquid Chromatography	APHA et al. (1998)
Phosphate (organic; inorganic)	µg-P/L	Liquid Chromatography	APHA et al. (1998)
Sulphate	mg/L	Liquid Chromatography	APHA et al. (1998)
Sodium	mg/L	Liquid Chromatography	APHA et al. (1998)
Potassium	mg/L	Liquid Chromatography	APHA et al. (1998)
Magnesium	mg/L	Liquid Chromatography	APHA et al. (1998)
Calcium	mg/L	Liquid Chromatography	APHA et al. (1998)
	mg/L	Extraction soxhlet	APHA et al. (1998)
Metals (Al, Cu, Fe, Cd, Pb, Cr, Mn, Zn, As, Hg, Ni, Se)	mg/L	Atomic Absorption Spectrophotometer	APHA et al. (1998)
Clorophyll a	µg/L	Extraction Etanol 80% Warm Spectrophotometric	Nusch (1980)
Pesticides	µg/L	Methods USEPA 8260, 8270 8151, 8082 liquid cromatography	APHA et al. (1998)
Total coliforms	NMP/100 mL	Incubation in defined substrate	APHA et al. (1998)
SEDIMENT			
Total phosphorus	mg-P/g sed	Colorimetric Method	Andersen (1976)
Total Nitrogen Kjeldhal	mg-NTK/g sed	Acid digestion, destilation, titration	APHA et al. (1998)
Organic Matter	%	Gravimetry	APHA et al. (1998)

Aquatic Macrophytes - gDW x m-2 (Moura Junior et al., 2015)

Table 1. Continued...

SURFACE WATER			
VARIABLES	**UNITY**	**METHOD**	**BASIC REFERENCES**
Total carbon-inorganic carbon	mg/g sed	Combustion at higt temperature. Infrared detection TOC – 5.000, SSM – 5000A	APHA et al. (1998)
Metals (Al, Cu, Fe, Pb, Cr, Mn, Zn, As, Hg, Ni)	mg/Kg sed	USEPA 3050B ver.2 – atomic absorption	APHA et al. (1998)
Granulmetry	%		APHA et al. (1998)
Pesticides (11 types – organochlorides, organophosphorus, carbamates.	µg/Kg sed	USEPA 8270, 8260B, 8081, 8082, 8141 – liquid cromatography	APHA et al. (1998)
AQUATIC BIOTA			
Phytoplankton & Cyanobacterias	org/ml	Phytoplankton & Cyanobacterias Sant'Anna (1984)	
Zooplankton	org/m^3	Pennak(1953), Matsumura-Tundisi (1999)	
Benthic macro invertebrates	Org/m^2	Mugnai et al. 2010	

Aquatic Macrophytes - gDW x m-2 (Moura Junior et al., 2015)

laboratory studies are an important and useful methodology to develop biological assessments (Chapman, 1992; Arocena and Conde, 1999).

Since the presence or absence of specific aquatic organisms depends on the physical environments, its associated habitats, and the water quality, sampling demonstrates the magnitude of the impacts.

5.2.4. Methods for biological sampling

5.2.4.1. Phytoplankton

60 liters of water were collected in the subsurface with a plastic bucket. The material was concentrated with a net mesh size 20µm. Samples were dispensed in a plastic container of 250ml and fixed in formalin, 4%. The analysis of the phytoplankton was carried out routinely with an optical microscope with 200x enlargement in a Sedgwick Rafter camera. Analysis of the phytoplankton with an inverted microscope, in sedimentation chambers was also performed. Sub samples of 1 ml were examined routinely. Manuals and papers for phytoplankton identification, were those of Geitler (1932), Uthermöl (1958), Bicudo (1965), Prescott (1966), Huber-Pestalozzi (1968), Bourrely (1968, 1970, 1972), Bicudo and Bicudo (1970), Sant'Anna et al. (1988), Hustedt (1991), Komàrek (1991) and Bicudo et al.(2005). Density of organisms was expressed in organisms/litre. Classification of phytoplankton was made up to genera.

Sampling for cyanobacteria was performed with a collection of 250 milliliters of water, in the surface, preserved with formalin 2%. Identification and determination of number of cells was carried out routinely by the use of a inverted microscope Zeiss; routinely samples were analyzed after sedimentation in chambers of 2,5, 10 ml. Density of organisms was expressed in number of cels/ml.

5.2.4.2. Zooplankton

Zooplankton samples were collected with a conic net in horizontal tows -mesh size of the net 68µm.

Rotifers, Protozoa and Copepod nauplii were classified under binocular microscope with magnification of 200x; 1 ml sub sample was dispensed in a Sedgwick Rafter camera.

Larges organisms such as Copepod and Cladocera were analyzed under a binocular microscope in 5-10 ml sub samples, with magnification of 100x.

Density of zooplankton organisms was expressed in number of organisms/m^3. References for zooplankton identification:Edmondson (1959), Koste (1978), Dussart (1984), Dussart and Defaye (2001), Matsumura-Tundisi et al. (1991), Matsumura-Tundisi and Silva (1999), Matsumura-Tundisi (1999), Smirnov (1971), Mizuno (1964) and El Moor-Loureiro (1997).

5.2.4.3. Benthic macro invertebrates

Sampling was carried out by using a quick net; an Eckman-Petersen collector for organic sediment; a Van Veen sampler for sandy or pebbles sediment. Samples were dispensed in plastic bottles and fixed with formalin 8%. In the laboratory samples were sorted out, biological material was analyzed under binocular microscope with a magnification of 100%. Classification up to family was used for macro invertebrates. Density of organisms was expressed in number/cm^3 sediment.

References for benthic organisms identification: Pérez (1996) and Mugnai et al. (2010).

5.2.4.4. Aquatic macrophytes

The occurrence of aquatic macrophytes was carried out by visualization of the species, both on the water and in the margins for the identification of amphibian forms. Unidentified plants by viewing were collected and placed between sheets of newspaper, cardboard, pressed between wooden slats, kept in an oven for at 40° C for 72 h and then kept in a freezer at –20° C for 96 h for assembly of herbarium specimens.

To determine the biomass, 3 square plots of 0.5 × 0.5 m were sampled, washed to remove debris and dried at 70° C until constant weight. The biomass was obtained by the dry weight (DW) per unit of area expressed in gDW. m^{-2}.

A qualitative assessment of aquatic macrophytes infestation was performed at each sampling site, assigning the following scale: Level 0: absence of macrophytes; Level I: only the presence; Level II: mild infestation; Level III: medium infestation; Level IV: severe infestation; and Level V: critical infestation. Fauna associated with aquatic macrophytes was also studied and classified up to family (Moura Junior et al., 2015).

6. Discussion

The methodology of sampling and the design of limnological surveys and research followed the conditions of structure and function of the Xingu River ecosystem, and its spatial and temporal complexity. The evaluation of the water quality parameters were also permanently compared with the Brazilian environmental regulations for water quality (CONAMA 357) and the designed water use. Geographical features of the region, the water uses (present and future), pollution sources and the hydrological cycles, were the main features that were the basis for the assessment programme. The spatial distribution of water, quality with great number of stations, the evaluation of trends with high frequency of sampling on in depth inventories with pollutants, were the basis of the monitoring of water quality, established. The operations on water quality assessment and limnological surveys, also, followed the strategies of: basic surveys, operational surveillance, emergency surveys, impact surveys, and early warning surveillance as described by Chapman (1992), Carlson (1977) and Tundisi and Matsumura-Tundisi (2008, 2012, 2013b).

7. Perspectives

The multipurpose monitoring carried out at the Xingu River in the region of influence of the future Belo Monte Power Plant is a information system that will be fundamental to assess the water quality and the limnological status of the river, as well as to provide a basis for the development of future scenarios when the reservoirs starts their operation (Colwell et al., 2004). The data bank this provided with the intensive sampling is fundamental also to be the basis for the modeling effort prepared for evaluating impacts on the water quality and for designing mitigation strategies. River/reservoir ecosystems, support a wide variety of activities such as water supply for drinking water, irrigation, navigation and recreation, besides, as in the case of Belo Monte Power Plant units, production of energy (Garzon, 1984; Junk and Mello, 1987). Progressive urbanization, pollution, and new economic developments triggered by the Power Plant units, will affect water quality, the river/reservoir limnology and the aquatic biota at all trophic levels. The organization and operation of a limnological survey and water quality assessment is a fundamental process and a platform that will lay the foundations for a follow up of the future changes that certainly will occur at the Belo Monte Power Plant Unit and Xingu River (Tundisi, 1999; Brasil, 2001; Jorgensen et al., 2012).

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Annex A. List of sampling stations in the lower Xingu River.

Table 1A. Monthly sampling stations.

REGION	SITE	LOCATION	
		E[a]	S[b]
Belo Monte Construction Site	PCIBM	411710	9654776
	PACBM-J	409329	9655379
	RXTP	411518	9657155
	SEBM/IGSA	411411	9653158
	PACBM-M	408904	9654630
	RX-07	412101	9655603
	Downstream wastewater treatment plant	409813	9657777
	Water intake for drinking purposes	411636	9656065
Workers Village		418528	9656427
		417479	9656648
Main Reservoir Construction Site	PACPIM-J/ Downstream wastewater treatment plant	399414	9617647
	PACPIM - M	399313	9621524
	SEPIM	394953	9620243
	RX 22	393341	9616080
	PIMENTAL	396711	9622747
Channel Construction and Dikes	PTO 1	397829	9636748
	PTO 2	393499	9627763
	PTO 3	401950	9636672

[a] E (East). [b] S (South) coordinates expressed in Universal Transverse Mercator (UTM).

Table 2A. Weekly sampling sites near main reservoir.

REGION	SITE	LOCATION	
		E[a]	S[b]
XINGU RIVER	PIM 1	393707	9622013
	PIM2	393625	9619797
	PIM 3	393721	9618982
	PIM 4	393606	9617918
	PIM 5	393517	9616490
	PIM 6	392994	9614535
	PIM 7	394720	9616038

[a] E (East). [b] S (South) coordinates expressed in Universal Transverse Mercator (UTM).

Table 3A. Weekly monitoring transmission lines.

REGION	SITE	LOCATION	
		E[a]	S[b]
ROADS	PACBM-M	408918	9654830
	IGATU	416616	9654462
	IGCHOCAÍ	420015	9654208
	PCIBM	411710	9654776
DASH KM 50	SEBM = IGSA	411411	9653158
DASH KM 40	IGTR40	401380	9659722
EAST-WEST	PTO 02	393499	9627763
	IGLH	394393	9627799
DASH KM 55	IGPAQ	412785	9632254
	IGTIC	416972	9635945
	IGCAJ	416759	9639494
	IGCO	416941	9641996
DASH KM 27	IGPAQ-M1	396299	9638667
	IGPAQ-M2	396333	9638686
	PACPIM-J	401942	9621770
	IGARAPÉ TRV 27	401773	9624030

[a] E (East). [b] S (South) coordinates expressed in Universal Transverse Mercator (UTM).

Table 4A. Sampling sites every three months.

REGION	SITE	LOCATION	
		E[a]	S[b]
UPSTREAM FUTURE XINGU RIVER RESERVOIR	RX 19	340308	9594378
XINGU RIVER IN THE SITE OF FUTURE XINGU RIVER RESERVOIR	RX01	364567	9622460
	RX 02	364825	9642028
	PAN 02	362587	9642191
	ALT 02	364918	9646170
	AMB 02	367145	9646750
	RX 18	369016	9645307
	RX 24	380375	9643752
	RX 25	385884	9627996
	RX 03	393609	9621881
	IGLH	394393	9627799
	IDM	397174	9624564
	PIMENTAL*	395955	9619993
DOWNSTREAM XINGU RIVER RESERVOIR (VOLTA GRANDE)	RX23	399847	9611758
	RESSACA*	395716	9605109
	FAZENDA*	397063	9605831
	RX04	398892	9604506
	RX20	410981	9612559
	RX05	419119	9611979
	RX06	422128	9613197
	BAC02	423341	9608322
	BAC03	436647	9595949
	RX21	416882	9632483
	RX17	423568	9654245

[a] E (East). [b] S (South) coordinates expressed in Universal Transverse Mercator (UTM). *Pimental, Ressaca and Fazenda are local names of sites.

Table 4A. Continued...

REGION	SITE	LOCATION	
		E[a]	S[b]
	IGCHOCAÍ	420015	9654208
	RX11	420042	9655929
SITES OF FUTURE MIDDLE RESERVOIR	IGPAQ	412785	9632254
	IGTIC	416972	9635945
	IGCAJ	418862	9639036
	IGCO	416941	9641996
	TURIÁ	414127	9648416
DOWNSTREAM POWER PLANT IN THE XINGU RIVER	RX 07	412421	9657260
	SEBM/IGSA	411411	9653158
	TUC 01	388040	9682481
	RX 15	3875534	9688205

[a] E (East). [b] S (South) coordinates expressed in Universal Transverse Mercator (UTM). *Pimental, Ressaca and Fazenda are local names of sites.