Aquatic Macrophytes of Itaipu Reservoir, Brazil: Survey of Species and Ecological Considerations

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ABSTRACT

In a survey of the aquatic macrophytes of the Itaipu Reservoir, we identified 62 taxa in 25 families and 42 genera. The highest number taxa was observed for the emergent macrophytes (40 taxa). Reduced fluctuation in water level, increased light penetration, and sediment enrichment by nutrients and organic matter following the formation of the reservoir favored the appearance of a species-rich community of submerged macrophytes (23% of the taxa identified). The aquatic macrophytes were found mainly near the mouths of the main tributaries of the reservoir, in shallow area of depth less than 2 meters. In addition to the shallow depth, the greater nutrient input from the tributaries and relative protection from wind explained this distribution. Among the species found, Egeria najas *merits mention for its occurrence in all localities sampled, with biomass values varying between 98 and 186 gDW/m^2. Some potential nuisance species such as* Eichhornia crassipes, Salvinia auriculata, *and* Pistia stratiotes *also deserve attention, since they were also observed to be covering large areas of Itaipu Reservoir.*

Key words: Nuisance species, aquatic macrophytes, Itaipu reservoir, *Egeria najas*, *Egeria densa*

INTRODUCTION

Reservoir construction causes changes in bodies of water, most obviously reduction in current velocity and increases in shoreline development, water transparency, and sediment stability (Tundisi *et al*., 1993). Moreover, depending on the limnological characteristics of the river, the reservoir may undergo rapid eutrophication, which is most accentuated in the first reservoirs of a series (Bini, 1995). These changes can lead to the invasion and rapid development of different species and ecological types of aquatic macrophytes (Pieterse & Murphy, 1990).

Floristic surveys represent the first phase of studies envisioning the identification of potential nuisance species and management of the aquatic macrophyte community (Wade, 1990). In spite of the large number of reservoirs constructed in Brazil (130 reservoirs more than 100 km^2 in the southeast alone; Agostinho *et al.*, 1995) and the ecological importance of aquatic macrophytes (Esteves, 1988), studies on this community in reservoirs have just began in Brazil. Accordingly, floristic surveys are important in view of the fact that excessive growth of these plants can generate problems for multiple uses of reservoirs such as recreation, fishing, water supply, and generation of electrical power.

In the present study, a survey of species composition of aquatic macrophytes along the left shore of the Itaipu Reservoir was undertaken, with the objective of identifying the species with greatest potential to cause problems for multiple uses of the reservoir. The biomass, distribution, and influence of the principal macrophyte species on some physical and chemical characteristics of the water were also considered.

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STUDY AREA

Itaipu Reservoir (24°05' to 25°33'S and 50°00' to 50°30'W) is 1350 km^2 in area, 170 km long, with a mean width of 7 km (Fig. 1). The mean depth is 21.5 m and the theoretical residence time of the water is 40 days. The water level fluctuates less than 1 m annually. The central body of the reservoir can be considered mesotrophic, while the arms along the left (Brazilian) shore may be mesotrophic or eutrophic, depending on the time of year (Andrade *et al*., 1988).

Water characteristics of the 9 surveyed arms shows marked differences between tributary mouths (regions more frequently colonized by aquatic macrophytes) and open waters.

Table 1. Abiotic limnological variables in the 8 arms of the left side of the Itaipu Reservoir. Means, standard deviation (in parentheses), and range of variation are presented.

Parameter	Tributary mouth	Open water
Secchi (m)	1.0 (0.5)	1.5 (0.4)
Elec. conductivity (µS/cm)	64 (24)	48 (10)
pH	7.5 (0.5)	7.5 (0.2)
Total alkalinity (µEq/l)	390 (140)	350 (110)
Kjeldahl-N (µg/l)	490 (180)	440 (140)
Total-P (µg/l)	51 (59)	17 (10)

The reservoir has several environmental characteristics that favour the development of different species of aquatic macrophytes. Primarily, the annual mean temperature of 21°C recorded in the area influenced by the reservoir does not strongly restrict the development of these plants. On a regional scale, the floodplain of the Upper Paraná River upstream from the reservoir is a continuous source of propagules of many species.

METHODS

Subsurface water samples were collected from two areas of the 8 principal arms along the left shore of the reservoir in the open water of the arms (near the main body of the reservoir), and the other near the mouths of the tributaries (Fig. 1). Macrophytes were also collected in these same arms. The collections were made during 3-14 December 1995 and 15-28 September 1996. The monitoring carried out monthly since April 1997 until April 1998 did not add new species.

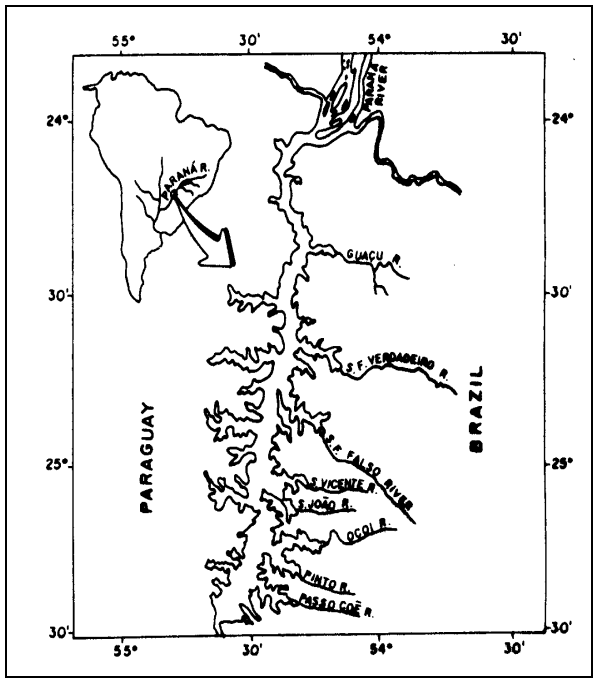

Figure 1. Lateral arms of the Itaipu Reservoir (Brazilian side) visited during the survey.

Because of the large size of the reservoir, an initial aerial survey, with helicopter was carried out to locate the areas most densely colonized by aquatic macrophytes and to maximize efficiency of the fieldwork. Emergent and free-floating macrophytes and species with floating leaves were collected manually. Submerged plants were collected with the aid of a Petersen grab and hooks.

In the arms of the São João, Ocoí, São Francisco Falso, and São Francisco Verdadeiro Rivers, we evaluated the biomass of *Egeria najas, Potamogeton pusillus, Salvinia auriculata, Eichhornia crassipes,* and *Pistia stratiotes*. For the first two (submerged) species, we collected all plant matter (leaves, petioles, and flowers) contained within 0.25 m^2 quadrats. For the other (free-floating) species, we collected all plant parts (leaves, petioles, flowers, and roots)

contained within 0.50 m^2 quadrats. The samples were dried to constant weight (DW) at 105 ^oC.

The frequency of occurrence of *E. najas*, the species, which Itaipu managers are more concerned about, was evaluated in the arms of the São João, São Vicente, and São Francisco Falso Rivers. In these localities, we established 25, 11, and 26 collection points respectively, located in the littoral zone demarcated in the map. The number of localities was chosen according to arm heterogeneity and size. At each point the presence or absence of *E. najas* was recorded. The results are presented as percentage of points in which this species was registered.

RESULTS AND DISCUSSION

List of taxa and ecological groups of aquatic macrophytes

A total of 62 taxa belonging to 25 families and 42 genera were identified. Of these, 42 taxa were identified to species level (Table 2). The family Poaceae was best represented, with 14 taxa, next the Characeae with 7 taxa, and the Polygonaceae with 4 taxa. The families Pontederiaceae, Potamogetonaceae, and Hydrocharitaceae were each represented by 3 taxa. Only 1 or 2 taxa of each of the remaining families were identified.

The number of species (62 taxa) contrasted with other surveys in large reservoirs in South America. In Guri Reservoir (Venezuela), an oligotrophic, blackwater environment with an area (4,500 km^2) three times greater than the Itaipu, only 27 taxa of aquatic macrophytes were recorded (Vilarrubia & Cora, 1993). The higher number of species in the Itaipu may be associated with input of nutrients from its tributaries. According to Andrade *et al.* (1988), the Itaipu backwaters are meso-eutrophic. Additionally, the moderate water levels variations, which oscillate aproximately one meter per year in the Itaipu, may also favour colonization by different species. It has been shown for other reservoirs that water fluctuations of up to three meters increase the aquatic macrophyte species richness, but higher fluctuations cause its decrease (Rørslett, 1991).

The majority (64%) of the taxa identified in Itaipu Reservoir were emergent macrophytes. Nevertheless, Itaipu is rich in submerged rooted taxa (14 taxa, 23% of the total) compared to undammed environments of the Paraná River, where there are still floodplains. In the Argentine stretch, for example, none of the environments that connect with the annual flood pulse of the Paraná River have submerged macrophytes (J. J. Neiff, personal communication). A similar situation is observed in the floodplain of the Upper Paraná upstream from Itaipu, where only five taxa of submerged macrophytes have been recorded (S.M.Thomaz, personal observation).

The changes caused by construction of the reservoir therefore, created a favorable environment for the development of submerged rooted macrophytes. This statement is supported when we consider the data from a survey of the Itaipu area before the reservoir was constructed (Surehma, 1980), which documented only five species of submerged macrophytes. Although these results deserve caution, since only the main tributaries were surveyed, *E. najas*, a common species in Itaipu nowadays, was not found at that time. In this way, it is postulated that the factors contributing to the development of the submerged macrophytes following reservoir construction probably include the reduction in water velocity, increase in system stability when compared to the natural floodplains (the fluctuation in water level being usually lower than 1 meter per year at Itaipu), increased light penetration, and enrichment of sediment by nutrients and organic matter.

Spatial distribution and biomass

The aerial survey established that the aquatic macrophytes were distributed mainly in the upper parts of the reservoir arms, i.e in shallow areas of depth less than 2 meters, near the mouths of the tributaries. These locations have several characteristics that together account for the presence of macrophytes: greater nutrient input, greater sedimentation rate, which reduces the depth and increases the area available for colonization, and protection from wind.

Table 2. Taxa of aquatic macrophytes recorded in the arms of the Brazilian side of the Itaipu Reservoir. EM = emergent; FL = floating; FS = free submerged; RF = rooted with floating leaves; SU = submerged

Families	Taxon	Ecological group
Acanthaceae	*Hygrophila guianensis* Nees.	EM
Alismataceae	*Echinodorus* cf. *grandiflorus* Mitch	EM
	Sagittaria montevidensis Chan et Scech	EM
Amaranthaceae	*Alternanthera philoxiroides* (Mart.) Griseb	EM
	Alternanthera sp	EM
Apiaceae	*Eryngium* sp	EM
	Hydrocotyle cf. *ranunculoides* L.	EM
Araceae	*Pistia stratiotes* Linn.	FL
Capparaceae	*Cleome spinosa* L.	EM
Characeae	*Chara braunii* Gmel	SU
	Chara guairensis R. Bicudo	SU
	Chara sp	SU
	Nittella acuminata C. A. Braun ex. Wallman	SU
	Nittella furcata (Roxb. Ex Bruz.) Ag., en R.D. Wood	SU
	Nitella furcata subsp. *Mucronata* (A. Braun) R.D. Wood	SU
	Nittella subglomerata A. Braun	SU
Commelinaceae	*Commelina nudiflora* L.	EM
Convolvulaceae	*Ipomoea* sp	EM
Cyperaceae	*Cyperus sesquiflorus* (Tor.) Mattf. et Kiik	EM
	Cyperus ferax L. C. Rich	EM
	Cyperus diffusus Vahl.	EM
	Eleocharis spp.	EM
	Rynchospora corymbosa L.	EM
	Scleria sp	EM
Euphorbiaceae	*Caperonia castaneifolia* (L.) St. Hil.	EM
Haloragaceae	*Myriophyllum brasiliense* Comb.	EM
Hydrocharitaceae	*Egeria najas* Planch.	SU
	Egeria densa Planch.	SU
	Ottelia sp	SU
Lemnaceae	*Lemna* sp	FL
	Spirodela sp	FL
Lentibulariaceae	*Utricularia* spp	FS
Menyanthaceae	*Nymphoides humboldtiana* (H.B.K.) Kuntze	RF
Najadaceae	*Najas* sp	SU
Nymphaeaceae	*Nymphaea* sp	RF
Onagraceae	*Ludwigia* cf. *suffruticosa* (L.) Hara.	EM
Poaceae	*Andropogon* sp	EM
	Coix lacryma-job L.	EM

Table 2: cont.

Families	Taxon	Ecological Group
Poaceae	*Eriochloa punctata* (L.) Desv.	EM
	Hymenachne amplexicaulis (Rudge) Nees	EM
	Panicum cf. *dichotomiflorum* Michx	EM
	Panicum maximum Jacq.	EM
	Panicum mertensii Roth	EM
	Panicum pernambucense (Sprengel) Mez	EM
	Panicum cf. *repens* L.	EM
	Paspalum conspersum Schrader ex Schulter	EM
	Paspalum repens Berg.	EM
	Penisetunn purpureum Schum	EM
	Setaria sp	EM
	Urochloa plantaginea (Link) Welster	EM
Polygonaceae	*Polygonum acuminatum* Kunth	EM
	Polygonum ferrugineum Wedd.	EM
	Polygonum punctatum Ell.	EM
	Polygonum hydropiperoides Michx.	EM
Pontederiaceae	*Eichhornia azurea* (Swartz) Kunth	EM
	Eichhornia crassipes (Mart.) Solms.	FL
	Pontederia cordata L.	EM
Potamogetaceae	*Potamogeton obtusifolius* Mert. & W. D. J. Koch	SU
	Potamogeton pusillus L.	SU
	Potamogeton sp	SU
Salvinaceae	*Salvinia auriculata* Aublet	FL
Typhaceae	*Typha domingensis* Pers.	EM

Of all the species of aquatic macrophytes found in the reservoir, *E. najas* required attention since it was recorded in all the arms investigated. Its wide distribution in the reservoir contrasted with its restricted distribution in the Paraná River floodplain. In the Argentine stretch, this species colonized only the most stable habitats such as small, highly transparent ponds with limited influence from the river (Neiff, 1986). *E. najas* was not only widely distributed, but occurs frequently and developed high biomass in the Itaipu Reservoir. This high frequency of occurrence was indicated by its presence at previously established sampling points in the arms of the São João (16% of points), São Vicente (36%), and São Francisco Falso (54%) Rivers. Biomass values for *E. najas* varied between 98 and 186 gDW/m^2 (Table 3). These results are high comparing to the biomass of *P. pusillus*, another submerged species found in Itaipu (Table 3).

Table 3. Biomass values for *E. najas* and *P. pusillus* recorded in arms of the left side of the Itaipu Reservoir in December 1995. Standard deviation in parentheses (n=3).

Species/arms	gDW/m^2
E. najas	
São João	186 (7)
Ocoí	157 (30)
Santa Helena	166 (25)
São Vicente	165 (17)
São Francisco Verdadeiro	98 (29)
São Francisco Falso	136 (45)
P. pusillus	
Ocoí	72 (44)

In some localities large mixed stands of floating macrophytes were observed. The Ocoí River debouches into the reservoir we observed a large area covered by *S. auriculata*, *P. stratiotes*, and *E. crassipes*. In spite of the extensive coverage, the biomass values (Table 4) were lower than

some values recorded for reservoirs in the State of São Paulo: 689 to 1,638 gDW/m^2 for *E. crassipes* (Esteves, 1982). It is appropriate to emphasize that free-floating species have a high growth rate. Cook (1990) noted that *E. crassipes* required only 13 days to double the area occupied, while *Salvinia* spp. required between 7 - 17 days. Thus, under favorable conditions, such as high nutrient input, extensive areas may be colonized in a short period of time.

Table 4. Biomass (gDW/m^2) values for floating species recorded in the arm of Ocoí River in December 1995 (n=3) and in September 1996 (n=2). Standard deviation in parentheses.

Species	Dec./95	Sep./96
P. stratiotes	48 (26)	159 (17)
S. auriculata	226 (111)	84 (10)
E. crassipes	66 (43)	#

Present but not recorded in quadrats randomly placed over the stands.

Potential nuisance species of aquatic macrophytes

According to Fernández *et al*. (1990), submerged aquatic macrophytes caused most problems in temperate aquatic ecosystems, while floating species were more troublesome in the tropics. Of the species recorded in Itaipu, several are potential nuisance species: the floating *E. crassipes, S. auriculata,* and *P. stratiotes*, and the submerged *E. najas, E. densa,* and *Chara* spp.

E. crassipes and *P. stratiotes* have been considered the main weed species in several countries of Central and South America (Fernández *et al.*, 1990). These authors also documented problems, though to a lesser degree, caused in several countries by *Eichhornia azurea, Typha domingensis, Myriophyllum brasiliensis* and *Salvinia auriculata,* all species found in Itaipu. *Egeria* was cited as one of the genera that rarely caused problems in waterbodies of the Americas, except in Chile. *Egeria najas*, however, was widely distributed in Itaipu and could be considered as the submerged species with greatest potential to interfere significantly with the multiple uses of the reservoir.

CONCLUSIONS

Construction of the Itaipu Reservoir favoured the development of a large number of aquatic macrophyte species, largely dominated by a few species. Those with the highest potential as nuisance species, however, belong to the groups of submerged and floating species, mainly *E. najas, E. densa, P. stratiotes, S. auriculata,* and *E. crassipes*.

Of the submerged species, *E. najas* was found in all the arms along the left shore of the reservoir, and was recorded with high frequency and high biomass values.

The aquatic macrophytes of Itaipu Reservoir were still in the initial phase of colonization, and remain restricted to the backwaters, specifically near the mouths of the tributaries. The great potential for development of floating macrophytes, however, which in this reservoir was associated with nutrient input (FUEM/Itaipu Binacional, 1997), requires caution. On the other hand, the great depth and low water transparency values of most of the reservoir indicated that massive development of submerged species such as *E. najas* would be restricted to certain backwater areas.

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RESUMO

Em um levantamento de macrófitas aquáticas realizado no reservatório de Itaipu foram identificados 62 táxons pertencentes a 25 famílias e 42 gêneros. O maior número de táxons foi representado pelas macrófitas emergentes (40 táxons). O surgimento de uma rica comunidade de espécies submersas (23% dos táxons identificados) parece ter sido favorecido pelas alterações decorrentes da formação dor reservatório, tais como redução da flutuação dos níveis de água, aumento da penetração de luz e enriquecimento do sedimento em nutrientes e matéria orgânica. As macrófitas aquáticas foram registradas principalmente próximo à foz dos tributários do reservatório, em áreas rasas (profundidade inferior a 2 metros). Além da reduzida profundidade, o maior aporte de nutrientes associado à proteção do vento explicam essa distribuição. Entre as espécies registradas, *Egeria naja*s merece destaque por ocorrer em todas as localidades visitadas com valores de biomassa entre 98 e 168 gPS/m^2. Algumas espécies potencialmente daninhas como *Eichhornia crassipes*, *Salvinia auriculata* e *Pistia straiotes* também merecem atenção, pois foram encontradas cobrindo amplas áreas de alguns braços do reservatório.

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