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Floristic survey and species richness of aquatic macrophytes in water supply reservoirs

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Abstract: The present study aimed a floristic survey of aquatic macrophytes in four water supply reservoirs (Iraí, Passaúna, Piraquara I and II) of the Iguaçu River basin, Paraná, Brazil. Sampling and herborization of biological material followed methods described in literature. The species were classified by life forms. We found 90 species in 57 genera and 36 families, were 52.7% are monospecific. The richest reservoir was Passaúna (40 spp.), followed by Iraí, Piraquara I and Piraquara II (36 spp. each). Cyperaceae was the most representative with 17 spp., followed by Asteraceae, Onagraceae and Polygonaceae (7 spp. each). Amphibious and emergent life forms were equally express throughout species (41% each). Since aquatic macrophytes structure and contribute to environment biodiversity, the present study can assist management and implementation of biodiversity conservation efforts.

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Introduction

Reservoirs are derived from rivers damming for industrial or public supply as well as power generation use. For public supply purposes, the State of Paraná have five reservoirs (Alagados Passaúna, Iraí, Piraquara I and II) located at the Iguaçu River basin. These reservoirs differ as to their trophic level (IAP 2009). The increase of nutrients in reservoirs water provides an increased proliferation of mostly aquatic macrophytes weeds species. The intense growing of such species can reduce the diversity of macrophytes and/or associated organisms, beyond inferring water multiple uses (*e.g.,* navigation, public supply and energy generation) (Pompêo *et al*. 2005).

However, in great conditions, aquatic macrophytes promote a central structuring role in aquatic ecosystems, promoting complex habitat that determines the abundance and biodiversity of aquatic flora and fauna (Thomaz and Bini 2003). In this context, studies of floristic composition of aquatic macrophytes contribute to biodiversity patterns and knowledge processes (Thomaz and Bini 2003; Pompêo and Moschini-Carlos 2003). The basic information contained in species lists assist monitoring management (Thomaz and Bini 1998, 2003; Pompêo 1999; Thomaz 2002) and may direct environmental classification (Maltchik *et al*. 2007).

The studies of floristic surveys of aquatic macrophytes in the Paraná State focuses on rivers, floodplain or energy supply reservoirs (Cervi *et al*. 1983; Souza *et al*. 1997; Thomaz and Bini 2003; Thomaz *et al*. 2004; Milne *et al*. 2005; Cervi *et al*. 2009). However floristic survey of aquatic macrophytes is only cited for one water supply reservoir (Rocha and Martins 2011). Thus, this study aimed to: 1) present aquatic macrophytes species richness, composition and biological forms in four water supply reservoirs of the Iguaçu river basin, Paraná, Brazil; and 2) discuss conservation (native species) or management (opportunistic species) of aquatic macrophyte in these environments.

Materials and Methods

The study was conducted in four urban reservoirs managed by the environmental sanitation company of Paraná State (SANEPAR): Iraí (25°23′55.85″ S, 49°05′57.18″W), Passaúna (25°30′01.35″ S, 49°22′20.20″ W), Piraquara II (25°29′49.01″ S, 49°03′55.95″ W), and Piraquara I (25°29′08.86″ S, 49°00′35.66″ W) (Figure 1). These reservoirs provide public water supply for the city of Curitiba and its metropolitan region in the State of Paraná, south of Brazil. Considering the trophic level, the reservoirs can be ranked as: Piraquara I (Mesotrophic/Oligotrophic), Passaúna (Mesotrophic), Piraquara II (Mesotrophic) and Iraí (Eutrophic) (IAP 2009).

The floristic survey includes collections made in 2007, 2009, 2011 and 2012 in four seasons. The aquatic macrophytes were collected by boat inspections along all the reservoirs extent. Furthermore visual inspections were made aiming to detect species presence along the reservoirs. The plants were collected using the methods in Pedralli (1990), photographed in their natural habitat, collected for identification and deposited in the Herbarium of the Federal University of Paraná (UPCB), Municipal Botanical Museum (MBM) and the Herbarium of the Pontifical Catholic University of Paraná (HUCP). For species identification, pertinent literature was studied, as well as comparison with the MBM herbarium specimens previously determined by experts. The classification followed the APG III (2009) for angiosperms; Buck and Goffinet (2000) for bryophyte and Smith *et al*. (2006) for nonflowering vascular plants. For authors correct nomenclature and quotation, and native species identification was used Forzza *et al*. (2012). Life forms were considered according to Irgang *et al.* (1984) and Pedralli (1990): 1) RS, rooted submerged; 2) FS, free submerged; 3) RF, rooted floating; 4) FF, free floating; 5) EM, emergent; 6) AM, amphibious; and 7) EP, epiphytes.

Results

The floristic survey resulted in 90 species, 57 genera and 36 families of aquatic macrophytes (Table 1) which 52.7% are monospecific. Only *Cuphea glutinosa* is endemic to the south and southeast of the country. *Ludwigia hookeri* is endemic only for the State of Paraná. The species *Centella asiatica*, *Drymaria cordata*, *Nympheae caerulea* and *Rumex obtusifolius* are not native but naturalized in Brazil. All Cyperaceae except for *Carex brasiliensis* and *Cyperus consanguineus* as well as Juncaceae (*Juncus micranthus* and *J. microcephalus*) are found in the Atlantic forest, but without citation for the State of Paraná. All other species are native and not endemic to Brazil (Forzza *et al*. 2012). The opportunist specie *Eichhornia crassipes* was reported only at Iraí reservoir; the most trophic of all, while *Salvinia auriculata* was reported at Passaúna and Piraquara II reservoirs.

Emergent and amphibious were the most representative life forms in all reservoirs. Respectively they represented 45% and 42.5% at Passaúna; 47.2% and 36.1% at Iraí; 38.8% and 36,1% at Piraquara I and; 52.7% and 25% at Piraquara II (Figure 2).

The most representative family for all reservoirs was Cyperaceae (17 spp.) followed by Asteraceae, Polygonaceae and Onagraceae (7 spp. each). The genera *Ludwigia* was the most representative (7 spp.) followed by *Polygonum* (6 spp.) (Table 1). Passaúna reservoir had the greater richness with 20 families, 30 genera and 40 species (Table 2). Cyperaceae had 8 spp.; highlighting *Pycreus decumbens* for its considerably presence along the reservoir (visual inspection); followed by Poaceae and Asteraceae (4 spp. each). The Iraí reservoir presented 18 families, 22 genera and 36 species (Table 2). Onagraceae was the richest (7 spp.) followed by Polygonaceae (4 spp.) and Poaceae (4 spp.). However, *Alternanthera philoxeroides* propagated intensely over the reservoir. The Piraquara I reservoir presented 20 families, 28 genera and 36 species (Table 2). Cyperaceae had 6 spp., followed by Polygonaceae (5 spp.). The most representative species for this reservoir was *Salvinia minima* and *Cyperus luzulae*. The Piraquara II reservoir presented 22 families, 26 genera and 36 species. Cyperaceae was the most representative with a total of 8 spp (Table 2).

Discussion

The great number of families, genera and species in reservoirs has indicated the considerable biological diversity of these environments (Thomaz *et al.* 1997, 1999; Rocha and Martins 2011). Therefore among the species often is notice the presence of aquatic macrophyte weeds due to the fact that reservoirs are considered stepping-stones for invasion species (Havel *et al*. 2014).

Among the families, the number of Cyperaceae species stood out considerably. The predominance of Cyperaceae was also observed by Moura-Junior *et al*. (2013—70 spp.), Cervi *et al*. (2009—22 spp.), and Pivari *et al*. (2011—10 spp.). The significant presence of Cyperaceae species is attributed to its perennial nature and tolerance to drought periods (Bove *et al*. 2003). Indeed representatives of this family were present in all four seasons analyzed as well as Poaceae species. However the rhizomes forming the

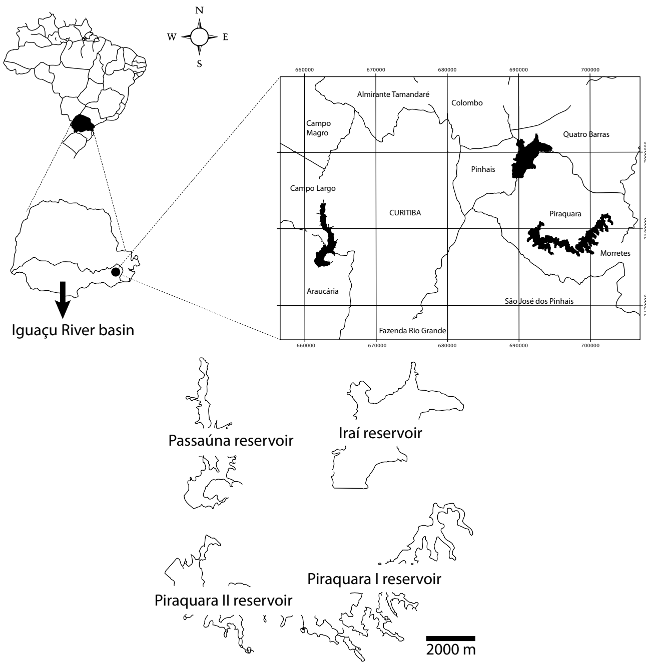

Figure 1. Geographic locality of the four water supply reservoirs studied.

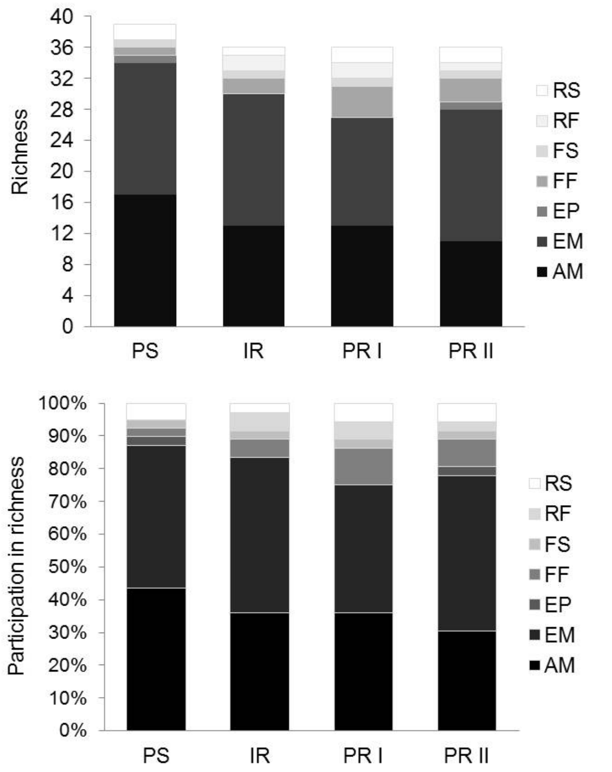

Figure 2. Species life form related to species richness and participation in richness of the four reservoirs. Life forms: RS, rooted submerged; RF, rooted floating; FS, free submerged; FF, free floating; EP, epiphyte; EM, emergent; AM, amphibious. Reservoirs: PS - Passaúna; IR - Iraí; PRI - Piraquara I; PRII - Piraquara II.

underground system are efficient in propagation (Pott *et al*. 1989) as well as the fruit dispersal made by water or wind (Judd *et al*. 2009). This leads us to consider that these qualities favor the floristic representation of these families. Asteraceae species are especially common in open regions. Its frequent presence is presumably from wind dispersal and/or the attract of inflorescences for generalist pollinators (Judd *et al*. 2009). Onagraceae and Polygonaceae species success is likely due to the pollination by bees, flies, moths and birds, reconciled with wind and water dispersal (Judd *et al*. 2009). *Ludwigia* species occur throughout Brazil, particularly in flooded areas. The representativeness of *Ludwigia* in floristic studies with aquatic macrophytes weeds is due mainly to certain floral and morphophysiological characteristics, such as the presence of floral resource (nectary) and pneumatophores. These structures allow representatives of genus greater efficiency in pollination and resistance to anoxic environments, *i.e.*, typically as eutrophic reservoir Iraí (8 spp. of *Ludwigia*) (Sousa and Lorenzi 2012).

Emergent and amphibious life forms were also a remarkable representation observed by other authors (Bove *et al*. 2003; Matias *et al*. 2003; Pereira *et al*. 2012). Amphibian and emergent species exhibit morphological and physiological adjustments which make them able to survive between terrestrial and aquatic environments (Moura-Junior *et al*. 2013).

Martins *et al*. (2008) reported the occurrence of 39 species in 18 reservoirs of five river basins of São Paulo State. The richness contrast with the present study may be related to the sampling method performed by Martins *et al*. (2008). According to Thomaz *et al*. (2004), the use of transects, even in large numbers, is still not enough for reliably sampled aquatic vegetation. Thus, the care in sampling becomes necessary since richness and diversity of species subsidize the management and conservation of aquatic environments.

The present study can be considered the third richest floristic survey for the Paraná State preceded by Cervi *et al*. (2009) with 117 spp and Ferreira *et al*. (2011) with 153 spp. Although the number of species can be affected by various environmental factors such as nutrients, fluctuation of water level, current velocity and spatial heterogeneity (Thomaz and Bini 2003). Pompeo *et al*. (2005) reported that if nutrients are not a limited factor at the environment, a great amount available can favor the proliferation of aquatic macrophytes weeds. Indeed in Iraí reservoir the proliferation of *Alternanthera philoxeroides* was considerably. The growth of opportunist species (*Eichhornia crassipes*, *Salvinia auriculata* and *Alternanthera philoxeroides*) hampers the colonization and development of aquatic macrophytes with low competition potential, thus reducing the ecosystem richness. Furthermore opportunist species promote

Table 1. List of aquatic macrophytes of four reservoirs of the Iguaçu river basin, Paraná, Brazil. Life forms: RS, rooted submerged; FS, free submerged; RF, rooted floating; FF, free floating; EM, emergent; AM, amphibious; EP, epiphyte. Collector number: CB, Cleusa Bona *et al*. (2007, 2009, 2011); AS, Alves-da-Silva *et al*. (2012).

FAMILY/SPECIES	LIFE FORMS	RESERVOIRS				COLECTOR NUMBER
		PS	IR	PR I	PR II	
Acanthaceae						
Hygrophila costata Nees	EM	X			X	AS 70; 97
Alismataceae						
Echinodorus grandiflorus (Cham. & Schltdl.) Micheli	EM		X		X	CB 477 AS 38; 91
Sagittaria montevidensis Cham. & Schltdl.	EM		X			AS 44
Amaranthaceae						
Alternanthera philoxeroides (Mart) Griseb.	EM	X	X	X	X	CB 419; 460; 467; 511; 527; 536; 571
Apiaceae						
Centella asiatica (L.) Urb.	EM	X				CB 383 AS 60
Araceae						
Lemna valdiviana Phil.	FF			X		CB 596
Spirodela intermedia W. Koch	FF			X		CB 598
Araliaceae						
Hydrocotyle bonariensis Lam.	RF		X			CB 418
Hydrocotyle ranunculoides L.f.	RF		X	X	X	CB 522; 608 AS 40; 111
Asteraceae						
Austroeupatorium picturatum (Malme) R.M. King & H. Rob.	AM	X				CB 396
Bidens laevis (L.) Britton, Sterns & Poggenb	AM		X			AS 130
Erigeron maximus (D. Don) DC.	AM			X		CB 429
Pluchea sagittalis (Lam.) Cabrera	AM			X		CB 424
Senecio jurgensii Mattf.	AM	X		X	X	CB 549; 603
Solidago chilensis Meyen	AM	X				CB 405
Urolepis hecatantha (DC.) R.M. King & H. Rob.	AM	X				CB 406
Campanulaceae						
Lobelia hassleri Zahlbr.	AM				X	AS 107
Caryophyllaceae						
Drymaria cordata (L.) Willd. ex Roem. & Schult.	AM		X			CB 469

Table 1. *Continued.*

FAMILY/SPECIES	LIFE FORMS	RESERVOIRS				COLECTOR NUMBER
		PS	IR	PR I	PR II	
Commelinaceae						
Commelina erecta L.	AM		X			CB 459; 471 AS 43
Commelina diffusa Burm. F	AM			X		AS 131
Cyperaceae						
Carex brasiliensis A. St.-Hil.	EM				X	CB 528
Cyperus consanguineus Kunth	EM	X				CB 541; 545
Cyperus esculentus L.	EM	X				CB 408
Cyperus haspan L.	EM			X		CB 587
Cyperus luzulae (L.) Retz.	EM	X			X	CB 526; 531 AS 63; 69
Eleocharis acutangula (Roxb.) Schult.	EM	X			X	AS 53; 90
Eleocharis maculosa (Vohl.) Roem. & Schult.	EM	X				AS 59
Eleocharis montana (Kunth) Roem. & Schult.	EM			X	X	CB 589; 612 AS 81; 121
Eleocharis niederleinii Boeckeler	EM				X	AS 73
Eleocharis sellowiana Kunth	EM			X	X	CB 520 AS 117
Eleocharis subarticulata (Nees) Boeckeler	EM		X	X		CB 588 AS 41
Fimbristylis complanata (Retz.) Link	EM			X		CB 423
Fuirena incompleta Nees	EM	X				CB 402
Pycreus decumbens T. Koyama	EM	X	X			CB 472; 544; 556 AS 56; 129
Rhynchospora asperula (Nees) Steud.	AM		X			CB 410
Rhynchospora corymbosa (L.) Britton	AM	X	X	X	X	CB 403; 463; 507; 524; 550; 583; 604 AS 82
Rhynchospora marisculus Lindl. & Nees 25	AM				X	AS 84
Haloragaceae						
Myriophyllum aquaticum (Vell.) Verdc.	RS	X	X	X	X	CB 420; 461; 508; 543; 606
Hypericaceae						
Hypericum brasiliense Choisy	AM				X	AS 78
Hypericum rigidum A.St.-Hil.	AM			X		CB 432
Iridaceae						
Sisyrinchium vaginatum Spreng ssp. *marchio* (Vell.) Ravenna	AM				X	AS 77
Juncaceae						
Juncus micranthus Schrad. ex Meyers	EM	X			X	CB 386 AS 80
Juncus microcephalus Kunth	EM				X	CB 610 AS 92
Lamiaceae						
Hyptis fasciculata Benth.	AM	X				CB 384
Hyptis uliginosa A.St.-Hil. ex Benth.	AM				X	AS 95
Leutibulariaceae						
Utricularia gibba L.	FS	X	X	X	X	CB 518; 540; 601; 607 AS 108
Linderniaceae						
Lindernia rotundifolia (L.) Alston	AM		X			AS 42
Lythraceae						
Cuphea calophylla subsp. *mesostemon* (Koehne) Lourteig	AM		X			CB 417
Cuphea carthagenensis (Jacq.) J.Macbr.	AM	X	X	X		CB 382; 436; 465; 504
Cuphea glutinosa Cham. & Schltdl.	AM				X	AS 94
Malvaceae						
Pavonia guerkeana R.E.Fr.	AM	X				CB 391; 502
Mayacaceae						
Mayaca fluviatilis Aubl.	RS			X	X	CB 525; 569 AS 119
Melastomataceae						
Rhynchanthera dichotoma (Desr.) DC.	AM			X		CB 430
Nymphaeaceae						
Nymphaea caerulea Savigny	RF			X		CB 567

Table 1. *Continued.*

FAMILY/SPECIES	LIFE FORMS	RESERVOIRS PS	IR	PR I	PR II	COLECTOR NUMBER
Onagraceae						
Ludwigia elegans (Cambess.) H. Hara	EM	X	X			CB 399 AS 126
Ludwigia grandiflora (Michx.) Greuter & Burdet	EM		X		X	AS 29; 47;76; 89
Ludwigia hookeri (Micheli) H. Hara	EM		X			AS 35
Ludwigia leptocarpa (Nutt.) H. Hara	EM	X	X			CB 398 AS 127
Ludwigia longifolia (DC.) H. Hara	EM		X	X	X	AS 48; 85;115
Ludwigia peruviana (L.) H. Hara	EM		X	X		CB 412; 413; 426
Ludwigia sericea (Cambess.) H. Hara	EM	X	X	X	X	CB 401; 414; 427 AS 34;106
Orchidaceae						
Habenaria paranaensis Barb.Rodr.	EP				X	AS 104
Habenaria repens Nutt.	EP	X				CB 554
Plantaginaceae						
Gratiola peruviana L.	AM		X			AS 46
Poaceae						
Luziola peruviana Juss. ex J.F.Gmel.	AM	X			X	AS 50; 68; 105
Panicum aquaticum Poir.	AM		X			AS 45
Panicum repens L.	AM	X	X			CB 385; 422; 473
Panicum schwackeanum Mez	AM	X	X	X	X	CB 609 AS 31; 49; 99
Paspalum mandiocanum Trin.	AM	X				AS 67
Polygonaceae						
Polygonum acuminatum Kunth	EM		X	X		CB 431; 457; 506; 576 AS 30
Polygonum hydropiperoides Michx.	EM	X	X	X	X	CB 572 AS 32; 71; 74; 75; 96
Polygonum meisnerianum Cham.	EM	X	X	X		CB 393 AS 37; 116
Polygonum persicaria L.	EM	X				CB 380
Polygonum punctatum Elliott	EM		X	X		CB 433; 475
Polygonum stelligerum Cham.	EM				X	AS 83
Rumex obtusifolius L.	EM			X		AS 434
Pontederiaceae						
Eichhornia crassipes (Mart.) Solms	FF		X			CB 481
Heteranthera zosterifolia Mart.	EM				X	AS 87
Pontederia lanceolata L.	EM		X			CB 486 AS 33
Potamogetonaceae						
Potamogeton polygonus Cham. & Schltdl.	RS	X				AS 64
Rubiaceae						
Diodia alata Nees & Mart.	AM	X		X		CB 390 AS 114
Diodia saponariifolia (Cham. & Schltdl.) K.Schum	AM	X		X		CB 381 AS 112
Oldenlandia salzmannii (DC.) Benth. & Hook.f. ex B.D.Jacks.	AM	X	X	X	X	CB 389; 582 AS 58; 98; 110; 120
Solanaceae						
Solanum pseudocapsicum L.	AM	X				CB 392
Typhaceae						
Typha latifolia L.	AM	X				AS 66
Xyridaceae						
Xyris jupicai Rich.	AM			X		AS 122
Ricciaceae						
Ricciocarpus natans (L.) Corda	FF			X		CB 565
Salviniaceae						
Azolla filiculoides Lam.	FF		X	X	X	CB 562 AS 26; 109
Salvinia auriculata Aubl.	FF	X			X	AS 102; 103
Salvinia minima Baker	FF				X	CB 611 AS 101; 118

decrease pH (Pedralli 2003); retention of nitrogen and phosphorus; increased biochemical oxygen demand (BOD); phytoplankton alteration, substrate retention, biodiversity reduction, and tubing obstruction (Thomaz 2002) raising the costs in reservoirs management (Pompêo 1999).

The present survey reported relevant species richness in water supply reservoirs of the Iguaçu River basin. The endemism is restricted to the south, southeast and Paraná State for *Cuphea glutinosa* and *Ludwigia hookeri* respectively. The presence of opportunist species as *Alternanthera philoxeroides, Eichhornia crassipes*, and *Salvinia auriculata* must be considered, once in proliferation situation, they become problematic for noble reservoirs uses (navigation, public water supply and hydroelectric power generation). The present study is the first step to aquatic macrophytes community dynamics understanding. Moreover, for a correct management and implementation of biodiversity conservation efforts, basic information about the composition of communities is indispensable (Bini *et al*. 2006).

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