Control of the aquatic macrophyte *Luziola peruviana* Juss. ex Gmel by grass carp (*Ctenopharyngodon idella* Valenciennes, 1844) grazing

Controle da macrófita aquática *Luziola peruviana* Juss. ex Gmel por herbivoria da carpa capim *(Ctenopharyngodon idella* Valenciennes, 1844)

Sponchiado, M. and Schwarzbold, A.

Programa de Pós-Graduação em Ecologia Instituto de Biociências,
Universidade Federal do Rio Grande do Sul – UFRGS
Av. Bento Gonçalves 9500, prédio 43422,
Campus do Vale CEP 91501-970 Porto Alegre, RS, Brazil
e-mail: margarete.sp@hotmail.com; albano.schwarzbold@ufrgs.br

Biological Limnology

Abstract: Aim: The grass carp (*Ctenopharyngodon idella*) for the biological control of Peruvian watergrass (*Luziola peruviana*); **Methods:** The biomass of *L. peruviana* was estimated by sampling 15 square plots of 0.25 m^2. The fish were introduced in October and taken out in April of the following year, over four consecutive years, from 2004 to 2008. In this period were placed on average 241 $fish.ha^{-1}$, with initial weight of 369 g. A map of the surface area occupied by the plant was obtained from an aerial photograph (1:2000) before the introduction of the fish. Yearly estimate of grazed area was carried out 'in situ', along 10 transect lines with stakes placed within 20 m of each other; **Results:** The annual stock of *L. peruviana* in the pond was 0.985 kg of dry mass of stems and leaves per m^2. The average plant biomass consumed was 42.5 kg of dry $mass.fish^{-1}$, in a grazed area of 43 $fish.m^{-2}$; **Conclusions:** The grass carp was found effective in controlling the proliferation of *L. peruviana* in the shallow pond. The condition for this control is the existence of the water level allowing the access of fish to the plants for your consumption.

Keywords: emerged aquatic macrophytes, biological control, herbivory, pond.

Resumo: Objetivo: Controle biológico da grama-boiadeira (*Luziola peruviana)* com a carpa capim *(Ctenopharyngodon idella)*; **Métodos:** A biomassa de *L. peruviana* foi estimada com amostragem de 15 quadrados de 0,25 m^2. Os peixes foram colocados em outubro e retirados em abril do ano seguinte, com repetições durante quatro anos consecutivos, de 2004 a 2008. Foram colocados em média 241 $peixes.ha^{-1}$ por período e peso médio de 369 $g.peixe^{-1}$. O mapa da superfície do açude ocupada pelas macrófitas foi obtido de foto aérea (escala 1:2000) antes da colocação dos peixes. A medição anual da área pastejada foi feita "in loco" baseado na distribuição de estacas com intervalos de 20 m ao longo de 10 transectos; **Resultados:** A biomassa (MS) disponível da grama boiadeira representou um estoque anual de 0,985 kg de MS de colmos e folhas por m^2. A média da biomassa consumida da macrófita foi de 42,5 kg $MS.peixe^{-1}$, representando uma área pastejada de 43 $m^{-2}.peixe^{-1}.ano^{-1}$; **Conclusões:** A carpa capim foi eficiente no controle da *L. peruviana* em açude raso. A condição para este controle é a existência de água no nível que permita o acesso dos peixes às plantas para o seu consumo.

Palavras-chave: macrófita aquática emersa, controle biológico, herbivoria, açude.

1. Introduction

Large plains areas in Southern Brazil have been gradually occupied by irrigated rice cultivation, along with extensive cattle raise (Velez-Martin et al., 1998). Simultaneously, ponds were constructed to serve as water deposits for use in these activities.

Ponds were constructed by man from the impoundment of water, for economic purposes (Esteves, 1998). These environments are ecologically immature and tend to a natural succession, that increases aquatic communities due to their high rates of organic matter production and by their role in the cycling of nutrients, while supporting secondary production (Mercante et al., 2004; Starling, 2005).

The shallow pond margins in the rice plantation areas are gradually colonized by aquatic plants being the dominant *L. peruviana* (Poaceae) with reduction in water quality (Sponchiado and Schwarzbold, 2008). This process is accelerated by annual crops in the adjacent areas, with input of nutrients, which favor aquatic macrophyte multiplication.

L. peruviana is an aquatic macrophyte with distribution in wet environments and shallow lentic waters. It is a perennial species, amphibious, rooted, monoecious, with good capacity for regrowth, reproduction by seeds and stolons, vegetative growth all year and bloom in Spring and Summer (Boldrini et al., 2005). Their leaves cover soil or form semi-floating masses over shallow water (Kissmann, 1991; Irgang and Gastal, 1996; Pompêo and Moschini-Carlos, 2003). In terrestrial form, it is recognized as food for cattle, and in flooded or wet areas, as an aquatic plant. It is found from southern United States to Argentina (Balbuena et al., 1994). It thrives in Southern Brazil, favored by the humid subtropical climate and topography (either the plain topography, or slightly hilly formation).

Some producers in that region began to introduce grass carp (*Ctenopharyngodon idella*) using this grass as their food source.

This species of fish has been used for efficiently controlling the proliferation of aquatic macrophytes (Aliev, 1976; Pípalová, 2002; Pípalová, 2003; Sutton and Vandiver, 2006) and filamentous algae (Hajra, 1987) in several regions of the world. Studies are needed to verify the efficiency of grass carp to remove the biomass produced by *L. peruviana*. The grass carp is a herbivorous fish in lowland rivers of eastern China with low speed and rich in aquatic vegetation. This species can tolerate temperatures from 0 to 33 °C (Arrignon, 1979; Makinouchi, 1980), and brief periods of low concentration of dissolved oxygen around 0.4 $mg.L^{-1}$ (Söderberg, 1995), important characteristics for survival in ponds in the summer.

The purpose of this study is to assess the capacity of grass carp in controlling the proliferation of *L. peruviana* in irrigated rice ponds.

2. Material and Methods

This research was conducted from October/04 to April/08 in a pond located in São Jerônimo, RS, Brazil (29° 59' 01.53" S and 51 40' 52.16" W). The climate is subtropical humid. Average Summer temperatures varied from 13.5 to 24.6 °C. The average annual precipitation is 1,467 mm (Bergamaschi et al., 2003).

The pond accumulates from rainwater and drainage of adjacent areas to provide the irrigation of rice, which is grown from December to March. To reach its maximum level it requires six months of rainfall (April to October). The pond has a surface area of 7.62 ha, with maximum depth of 1.24 m and it was built in 1994, with clay.

The map of the pond surface and with initial distribution of aquatic macrophytes was obtained from aerial photo in October/04, before placing the fish and georeferenced on the scale of 1:2,000.

In order to monitor grazing activity, 10 georeferenced lines were located across the pond, and along these, 94 stakes were placed, within 20 m of each other.

The maps of the grazed area were obtained during the four years of study, through in situ measurements , with the stakes of reference, always in October before the introduction of fish and in April after their removal.

Total biomass available of *L. peruviana* was estimated from the sampling method on 15 points consisting of square plots of 0.25 m^2 (Wetzel and Likens, 1991), randomly distributed in the pond. Biomass data were obtained from the collection of all plants on the plots. After splitting the stalks and leaves, which are the parts eaten by fish, they were washed, and dried in an oven at 70 °C until weight stabilization.

Limnological characterization of the surface water of the pond was performed through monthly collections of samples in ten points, in the longitudinal transect with and without aquatic macrophytes, at 20 cm depth, during 14 months (from October/04 to April/05, and from October/05 to April/06) . The following variables were analyzed: dissolved oxygen, total nitrogen, ammonia nitrogen, nitrate, total phosphorus, orthophosphate, pH, alkalinity, phenol, turbidity, color, conductivity and surface temperature, according APHA (1998) methods.

The determination of the remaining volumes of water from October to April was based on morphometric methods (Wetzel and Likens, 1991).

The fish introduction always took place in October, a period that coincides with the maximum water level in the pond and at the stage where the shoots and leaves of grass have reached the water surface. For the study periods of herbivory, 890 fish were placed in October/04, 1,200 fish in October/05, 1,100 fish in October/06, and 1,379 in October/07, with average weights of 381, 320, 320 and 515 g respectively.

The withdrawal of the fish was always held in April of the subsequent year, by means of a trawl after lowering the level of the pond with complete removal of the fish after 180 days of herbivory. The selection of fish was weighed in by random sampling, with individual weighing of 100 fish at the beginning and 50 fish at the end, in each year of study.

For the calculations, the following variables and equations were used:

- Average consumption of aquatic macrophyte biomass by fish (AC):
  $AC = DM \times GA/FNF$, expressed in $kg.fish^{-1}$, where:
  DM = dry mass of macrophyte in $kg.m^{-2}$;
  GA = grazed area in m^2, FNF = final number of fish.
- Area controlled by fish (ACF) - the average area with macrophytes grazed by fish:
  $ACF = GA/FNF$, in $m^{-2}.fish^{-1}$

3. Results

The average and standard deviation of the limnological variables registered over the years 2004/2005 and 2005/2006, were: dissolved oxygen = 5.2 ± 2.57 $mg.L^{-1}$, total nitrogen = 2.4 ± 1.77 $mg.L^{-1}$, ammonia nitrogen = 0.9 ± 0.79 $mg.L^{-1}$, nitrate = 0.3 ± 0.43 $mg.L^{-1}$, total phosphorus = 0.135 ± 0.004 $mg.L^{-1}$; orthophosphate = 0.092 ± 0.024 $mg.L^{-1}$, pH = 6.4 ± 0.70; color = 350 ± 150 Hazen; electrical conductivity = 27.2 ± 9.06 $\mu S.cm^{-1}$; phenols = 0.004 ± 0.001 $mg.L^{-1}$, surface water temperature (20 cm depth) = 25.7 ± 3.42 °C.

The loss of water volume in the first three periods of the study was due to evapotranspiration, infiltration and natural use for rice plantation. Only in the last period of the study, there was no water loss to rice irrigation (Figure 1).

The areas grazed in April in the four periods of study were 1.72, 1.88, 2.25 and 5.15 ha respectively (Figure 2), corresponding to a biomass removal of 16.95, 18.52, 22.17 and 50.74 ton DM.year^{-1} from 2004 to 2008 (Table 1).

The average biomass stock of *L. peruviana* (stems and leaves) was DM 0.985 kg.m^{-2}.year^{-1} spatially representing a biomass available in the pond of DM 9,852 kg.ha^{-1}.year^{-1}.

4. Discussion

Communities of aquatic macrophytes of lentic habitats are usually composed of species adapted to changes in water level, some are amphibious plants, supporting both submerged and emerged conditions. (Thomaz and Bini, 2003; Thomaz et al., 2004). In constructed ecosystems, such as hydroelectric reservoirs and irrigation ponds, changes in water level are determined by demand of use. Irrigation ponds in Rio Grande do Sul are deposits of water that, generally, have seasonal level variations, defined as: a period of high waters, coinciding with the highest rainfall in winter and spring, followed by a period of low waters

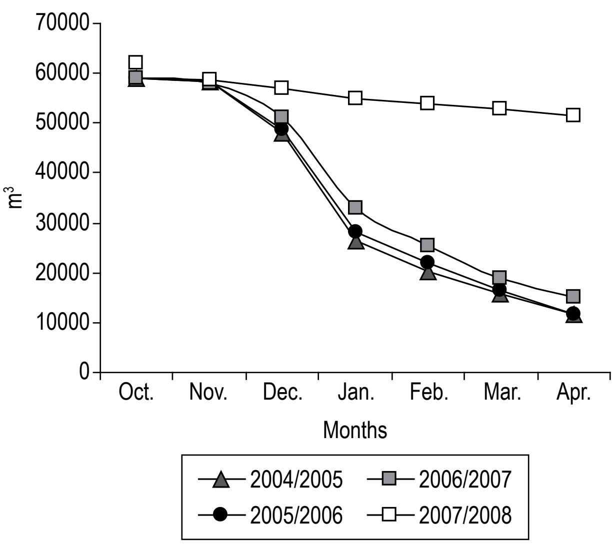

Figure 1. Remaining volumes of pond water (m^3) in São Jerônimo, RS, from October to April, 2004/2005, 2005/2006, 2006/2007 and 2007/2008.

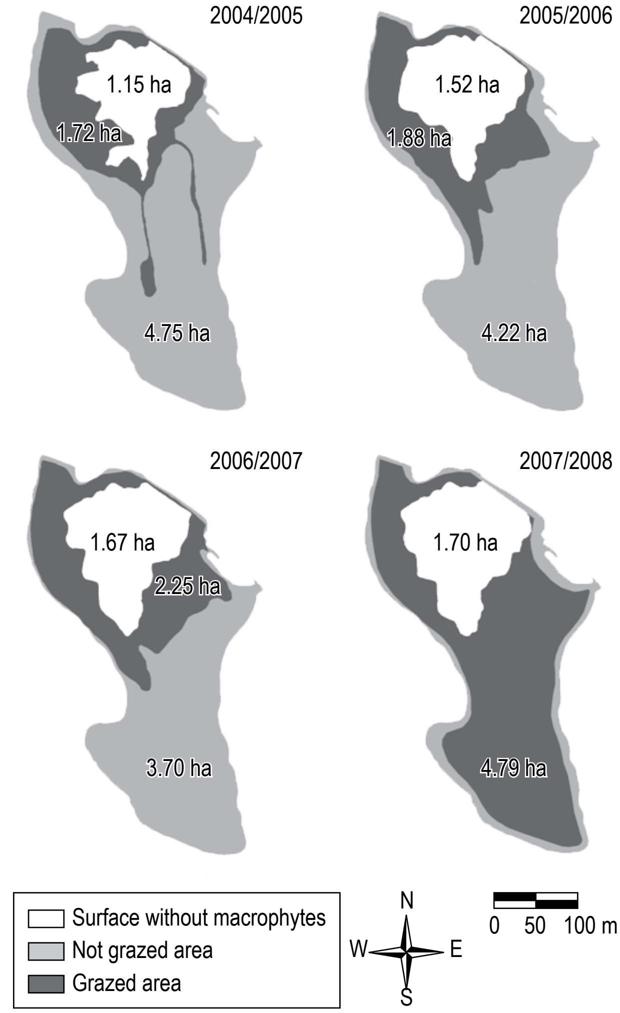

Figure 2. Pond maps indicating grazed area and not grazed remaining area, in 2004/2005, 2005/2006, 2006/2007 and 2007/2008.

Table 1. Quantity and average weights of grass carp placed in the weir, controlled area by fish in the periods between 2004 and 2008.

Period	2004/2005	2005/2006	2006/2007	2007/2008	Average
Initial fish nº	890	1200	1100	1379	1142
Final fish nº	420	506	502	1040	617
Initial fish weight (kg)	0.321 ± 0.078	0.320 ± 0.041	0.320 ± 0.030	0.515 ± 0.069	0.369
Fish density.ha^{-1}	55	66	76	144	85
Nº of fish placed.ha^{-1}	117	157	144	181	150
Macrophyte consumed (kg DM.fish^{-1}) (kg.fish^{-1})	40.3	36.6	44.2	48.9	42.5
Controlled area by fish (m^2)	41	37	45	50	43
Biomass removal (ton DM.year^{-1}) from 2004 to 2008	16.95	18.52	22.17	50.74	27.10

determined by the use of water for rice irrigation in summer. In normal years, in the study region, rainfall in winter and spring (until the end of October) is sufficient to attain the pond volume necessary to meet the irrigation needs for the following season when there is less precipitation.

The ponds built in Southern Brazil for irrigation of rice can be found in areas of low topography, requiring large areas for the accumulation of water due to the low depth of the water column. The grass *L. peruviana* is found in wet soils, wet/fully saturated soil at depths close to 0.8 m (Amato et al., 2007), due to its ability to rapidly develop root systems and stolons. As a result, they tend to colonize in a few years the entire shallow areas of ponds.

The biomass *L. peruviana* of stalks and leaves reached an average of 9.85 ton DM.ha^{-1}.year^{-1}. This production is higher than that of *Luziola spruceana*, subject to the kind of flood pulse of the Amazon fertile valley, where production was estimated at 5.7 ton DM.ha^{-1}.year^{-1} (Junk and Piedade, 1993). However, measures of production of *Echinochloa polystachya* (Poaceae) in the Jurumim pond (SP-Brazil) showed average of 19.34 tons DM.ha^{-1}.year^{-1} (Pompêo et al., 2001), *Zizaniopsis bonariensis* (Poaceae) in 28.7 ton DM.ha^{-1}.year^{-1} in lake in Rio Grande do Sul-Brazil (Ferreira et al., 2009) or even production of up to 57.6 tons DM.ha^{-1}year^{-1} in communities of *Paspalum fasciculatum* (Poaceae) in the fertile valley of the Amazon (Junk and Piedade,1993).

All values of limnological variables measured in the pond, were within the tolerance limits established for the grass carp (Cudmore and Mandrak, 2004)

Phenols are toxic to fish and usually found in environments with high levels of organic matter decomposition. In this study the concentrations were below the levels of toxicity to fish.

The gradual release of water for irrigation is the primary determinant in establishing the conditions for grazing and for the control of the aquatic macrophytes, determined by the number or biomass of fish placed per area unit.

The loss of volume of water in the first three periods of the study was due to evapotranspiration, infiltration and use for rice irrigation. Only in the last period of the study, there was no loss of water for rice plantation (Figure 1). In the first three years some areas became gradually inaccessible to fish. This condition differed in the fourth year, when there was no water release for the irrigated rice plantation, allowing fish access to macrophytes for grazing (Figure 2).

The higher pond water level in the year 2007/2008, provided access to the food, and the survival rate of fish was possible. In this study, the average area consumed by fish was 42.3 m^2 between October and April.

Thus, for other ponds of similar morphometric characteristics, similar use of its waters and similar composition of the aquatic communities, the same indicators of control might be applied.

However, after each period of grazing, there was a gradual increase in the area without macrophytes of 1.15 to 1.52 ha, 1.67 and 1.70 ha, respectively (Figure 2). This gradual decrease in vegetation area in the repeated practice of placing fish for grazing in subsequent years may indicate the condition of control or even eradication. If the aim is to control mapping of the increase or decrease in the coverage areas of macrophyte is a necessary practice, and, the decision on recommended density and biomass of fish may be based on this mapping. Interruptions of allotment of fish, for several years, could result in new colonization of the areas where the booths had been controled. Only monitoring over several years will evaluate the changes that occur.

The introduction of exotic species requires careful monitoring to avoid inadvertent changes in the structure of the community of native fish (Hrabik et al., 1998), changes in habitat, competition, hybridization, introduction of pathogens and diseases (Hall and Mills, 2000). Although in the pond under study all fish were removed after 180 days and the drainage was made through the PVC pipe with a mesh net to prevent escape of fish to another environment.

5. Conclusions

The herbivory of *L. peruviana* by grass carp was effective, featuring an effective biological control in manning, average weight per fish and period, used in this study.

The knowledge about the different uses of water from the pond, associated with conditions of rainfall in the region, and the characteristics and morphometric levels of water available, are basic conditions for the effectiveness of grazing for these herbivores fish.

Although *L. peruviana* presents capacity of regrowth, the study suggests a trend of gradual reduction of the colonized area, in repeated grazing, to characterize eradication in these conditions.

Acknowledgements

To CAPES (Coordenadoria de Aperfeiçoamento de Pessoal de Nível Superior) for doctor science fellowship to M. Sponchiado; to Agropecuária Jurerê Ltda and Mulltipeixes enterprise for supplying fish and logistical support and to Maria Angélica Oliveira for the English improving.

References

ALIEV, DS. The role of the phytophagous fish in the reconstruction of comercial ichthyofauna and biological melioration of water reservoirs. *J. Ichthyol.*, 1976, vol. 16, no. 2, p. 216-229.

AMATO, CG., SPONCHIADO, M. and SCHWARZBOLD, A. Estrutura de uma comunidade de macrófitas aquáticas em um açude de contenção (São Jerônimo, RS). *Rev. Bras. Bioc.*, 2007, vol. 5, no. 1, p. 828-830.

American Publication Health Association - APHA. *Standard Methods for the examination of water and wastewater*. 20 ed.

Washington: American Public Health Association; American Water Works Association; Water Environment Federation, 1998. 964p.

ARRIGNON, J. *Ecologia y piscicultura de águas dulces*. Madrid: Ediciones Mundi-Prensa, 1979. 365p.

BALBUENA, O., McDOWELL, LR. and STAHRINGER, RC. Suplentación con cobre inyectable en terneros e y vacas com hipocupremia. Estaciòn Experimental Coloria Benitez, 1994. Available from: <http:/www.inta.gov.br/benitez/info/documentos/alimen/art/alimen29.htm>. Acess in: 20/11/2005.

BERGAMASCHI, H., GUADAGNIN, MR., CARDOSO, LS. and SILVA, MIG. *Clima da Estação Experimental da UFRGS e região de abrangência*. Porto Alegre: UFRGS, 2003. 78p.

BOLDRINI, II., LONGHI-WAGNER, HM. and BOECHAT, SC. *Morfologia e Taxonomia de Gramíneas Sul-Rio-Grandenses*. Porto Alegre: UFRGS, 2005. 96p.

CUDMORE, B. and MANDRAK, NE. *Biological Synopsis of Grass Carp (Ctenopharyngodon idella)*. Burlington: Fisheries and Oceans Canada, 2004. 44p.

ESTEVES, FA. *Fundamentos de Limnologia*. Rio de Janeiro: Interciência - FINEP, 1998. 574p.

FERREIRA, TF., VAN NES, E. and MARQUES DM. Continuous growth of the giant grass *Zizaniopsis bonariensis* in subtropical wetlands. *Freshw. Biol*., 2009, vol. 54, no. 2, p. 321-330.

HAJRA, A. Biochemical investigations on the protein-calorie availability in grass carp (*Ctenopharyngodon idella*) from an aquatic weed (*Ceratophyllum demersum* Linn.) in the tropics. *Aquaculture,* 1987, vol. 61, no. 2, p. 113-120.

HALL, SR. and MILLS, EL. Exotic species in large lakes of the world. *Aquat. Ecossys. Heal. Managem.*, 2000, vol. 3, no.1, p. 105-135.

HRABIK, TR., MAGNUSON, JJ. and McLAIN, AS. Predicting the effects of rainbow smelt on native fishes in small lakes: evidence from long-term research on two lakes. *Can. J. Fish. Aquat. Sci.*, 1998, vol. 55, no. 6, p. 1364-1371.

IRGANG, BE. and GASTAL Jr., CV. de S. *Macrófitas Aquáticas da Planície Costeira do Rio Grande do Sul*. Porto Alegre: UFRGS, 1996. 290p. (Editado por: IRGANG & GASTAL Jr.)

JUNK, WJ. and PIEDADE, MTF. Biomass and primary-production of herbaceous plant communities in the Amazon floodplain. *Hydrobiologia*, 1993, vol. 26, no. 1, p. 155-162.

KISSMANN, KG. *Plantas Dominantes e Nocivas*. São Paulo: TOMOI; BASF, 1991. 608p.

MAKINOUCHI, S. Criação de carpas em água parada. *Inf. Agrop.*, 1980, vol. 6, no. 67, p. 30-47.

MERCANTE, CTJ., CABIANCA, MA. de A., COSTA, SV., SILVA, D. and ESTEVES, KE. Water quality in fee-fishing ponds located in the metropolitan region of São Paulo city, Brazil: an analysis of the eutrophication process. *Acta Limn. Bras.*, 2004, vol. 16, no. 1, p. 95-102.

PÍPALOVÁ, I. Initial impact of low stocking density of grass carp on aquatic macrophytes. *Aquat. Bot.*, 2002, vol. 73, no. 1, p. 9-18.

PÍPALOVÁ, I. Grass carp (*Ctenopharyngodon idella*) grazing on duckeed (*Spirodela polyrhiza*). *Aquacul. Inter.*, 2003, vol. 11, no. 4, p. 325-336.

POMPÊO, MLM. and MOSCHINI-CARLOS, V. *Macrófitas Aquáticas e Perifíton:* aspectos ecológicos e metodológicos. São Carlos: Rima Editora, 2003. 124p.

POMPÊO, MLM., HENRY, R. and MOSCHINI-CARLOS, V. The water level Influence on biomass of the *Echinochloa polystachya* (Poaceae) in the Jurumirim Reservoir (São Paulo, Brazil). *Rev. Bras. Biol.*, 2001, vol. 61, no. 1, p. 19-26.

SODERBERG, R.W. *Flowing Water Fish Culture*. Boca Raton: Lewis Publishers, 1995. 147p.

SPONCHIADO, M. and SCHWARZBOLD, A. Influência da macrófita aquática *Luziola peruviana* na dinâmica de um ecossistema açude raso. In *Anais do Seminário de Estudos Limnológicos em Clima Subtropical,* Março 27-29, 2008. Rio Grande: FURG, 2008. 1 CD-ROM.

STARLING, FLRM. Controle de macrófitas em reservatórios. In *Anais do Seminário Nacional Sobre Espécies Invasoras*, Abril 26-28, 2005. Belo Horizonte: SECTES, 2005. 1 CD-ROM.

SUTTON, DV. and VANDIVER Jr., VV. *Grass carp*: a fish for biological management of Hydrilla and other aquatic weeds in Florida. Florida: Departament of Fisheries and Aquacultural Sciences; University of Florida, 2006. 9p. Bulletin 867.

THOMAZ, SM. and BINI, L. *Ecologia e manejo de macrófitas aquáticas*. Maringá: Eduem, 2003. 314 p.

THOMAZ, SM., PAGIORO, TA., BINI, LM., ROBERTO, MC. and ROCHA, RRA. Limnological characterization of the aquatic environments and the influence of hydrometric levels. In THOMAZ, SM., AGOSTINHO, AA. and HAHN, NS. (Orgs.). *The upper Paraná River and its floodplain*: physical aspects, ecology and conservation. Leiden: Backhuys Publishers, 2004. p. 75-102.

VÉLEZ-MARTIN, E., MENEGHETII, JO. and SCHWARZBOLD, A. Relationships between waterbirds and wetlands in the west coastal plain, southern Brazil: methodology of wetland sampling design. *Verh. Inter. Verein. Limnol.*, 1998, vol. 26, no. 1, p. 2347-2349.

WETZEL, RG. and LIKENS, GE. *Limnological Analyses*. 2 ed. New York: Springer-Verlag, 1991. 391p.

Received: 08 January 2009
Accepted: 19 May 2009