Research Note

AQUATIC VEGETATION ASSESSMENT AT PORTUGUÉS AND CERRILLOS RESERVOIRS, PUERTO RICO[1,2]

Wilfredo Robles[*3], *Miguel Torres*[4] *and Francisco Orsini*[5]

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Waterbodies in Puerto Rico are constantly threatened by the introduction, establishment and spread of aquatic weeds. Their introduction is promoted by the aquarium and horticultural trade, as well as by travel and commerce via air and marine transportation. Once introduced, their dominance limits recreational use of waterbodies, and management operations in reservoirs used for potable water and flood control deteriorate. In Puerto Rico, the problem has worsened because of limited citizen awareness, wrong public perception of available management techniques and eutrophic man-made water bodies serving as suitable habitat for aquatic weeds. Currently the most troublesome aquatic weeds in Puerto Rico are waterhyacinth (*Eichhornia crassipes*), waterlettuce (*Pistia stratiotes*), alligatorweed (*Alternanthera philoxeroides*), hydrilla (*Hydrilla verticillata*) and giant salvinia (*Salvinia molesta*) (Robles, 2011). During the 1970s, botanists from the US Army Corps of Engineers (USACE) recognized the problem that waterhyacinth, waterlettuce and alligatorweed represented to several waterbodies in Puerto Rico (Gangstad, 1977; Rushing, 1974). Waterhyacinth and waterlettuce are free-floating aquatic weeds well established in such reservoirs as La Plata, Guayabal and Carraízo, and Cartagena Wildlife Refuge in Puerto Rico (Robles, 2011). Alligatorweed has been observed in many water bodies and drainage canals; however, its area of infestation has decreased due to successful biocontrol agents (Robles, 2011). Recent introductions of the submersed aquatic weed, hydrilla, and the aquatic floating fern, giant salvinia, are limited to a few locations in northern Puerto Rico (Robles, 2011). All five aquatic weeds cause negative ecological and economic impacts to water supply reservoirs, irrigation and drainage canals, private ponds, as well as estuaries and freshwater wetlands used as wildlife refuges (Robles and González, 2010). Specifically, waterhyacinth causes problems in the operation of hydroelectric plants, clogging dams and pumping facilities of aqueducts and sewer operations (Rushing, 1974; Gangstad, 1977). Other troublesome weeds like the facultative wetland species catclaw mimosa (*Mimosa pigra*) are wide-

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[3*]Professor, Department of Agro-environmental Sciences, University of Puerto Rico, Agricultural Experiment Station, Mayagüez Campus. Corresponding author, E-mail: wilfredo.robles2@upr.edu.

[4]Former undergraduate student from the Department of Agro-environmental Sciences, University of Puerto Rico, Mayagüez Campus.

[5]Former undergraduate student from the Department of Agro-environmental Sciences, University of Puerto Rico, Mayagüez Campus.

spread throughout many waterbodies in Puerto Rico, limiting their recreational use as well as shoreline access to water for humans and animals.

In the municipality of Ponce, two water reservoirs, Cerrillos and Portugués, were constructed in 1992 and 2015, respectively, by the USACE (2015) as flood risk management projects for southern Puerto Rico. According to González (2012), the Portugués reservoir alone could prevent flood risk to 40,000 people in southern Puerto Rico. Both reservoirs are currently being managed by the Department of Natural and Environmental Resources of Puerto Rico (DNER) and used for recreation and flood control programs. Cerrillos reservoir may be used for water supply with a water storage capacity of 59.1 million cubic meters. Its dam is located on the Cerrillos River and is part of the Bucaná River Basin. The smaller Portugués reservoir has a capacity of 15.2 million cubic meters, and its dam is located on the Portugués River as part of the Portugués River Basin. Aquatic vegetation assessments of these two reservoirs have not been performed. Considering the risk posed by aquatic weeds presence at water reservoirs, it was important to conduct an aquatic vegetation assessment to maintain the functionality of flood control programs at Cerrillos and Portugués reservoirs.

Hence, a reservoir survey was performed, between April and May of 2015, using the point-intercept method to assess aquatic vegetation (Madsen, 1999). The survey consisted of observing the presence of aquatic plant species in the water body by navigating by boat sequentially along an evenly spaced grid of points aided by global positioning systems (GPS). This survey method has been widely used in providing estimates of frequency of occurrence, temporal changes of plant communities, spatial distribution of aquatic plants within a waterbody as well as providing estimates of percent plant cover (Madsen and Wersal, 2018; Madsen and Wersal, 2017; Madsen et al., 2016; Madsen et al., 2015; Cox et al., 2014; Robles et al., 2011; Wersal et al., 2010; Madsen et al., 2008; Madsen et al., 2006; Wersal et al., 2006; Case and Madsen, 2004). Specifically, point-intercept has proven to be as accurate as line-intercept and requires less time and effort to perform (Madsen and Wersal, 2017; Floyd and Anderson, 1987).

The reservoir survey was set up using ArcGIS: ArcMap software version 10.2 (ESRI 2014) where a grid of survey points 100 meters apart was created over both reservoir boundaries (Figure 1). Both reservoir boundaries and survey points were transferred to a handheld GPS unit, Trimble model Juno[6], to perform the survey. The GPS unit was capable of 3-meter position accuracy, and all data were projected in Puerto Rico Universal Transverse Mercator (UTM) zone 20 N. One rake toss was performed at each survey point by deploying the rake over the side of the boat and allowing the rake to sink to the bottom to ensure documentation of submersed aquatic plant species. The presence of aquatic plant species observed at each point was recorded as "1". Due to low water level and limiting navigation, only 112 and 30 survey points were surveyed in Cerrillos and Portugués reservoirs, respectively. For each aquatic plant species, points labeled as "1" were added to obtain their total count.

Water quality at the time of aquatic vegetation assessment was determined at the same aquatic plant survey points. At each point, an YSI EXO2 Multiparameter probe was launched to measure the following parameters at 30-cm depth below the water surface: conductivity (µS/cm), temperature (°C), dissolved oxygen (mg/L), pH, total dissolved solids (mg/L) and total algae (Chlorophyll µg/L). The probe was calibrated by the manufacturer prior to starting field surveys. A Secchi Disk was lowered within the water column to obtain

[6]Company or trade names in this publication are used only to provide specific information. Mention of a company or trade name does not constitute an endorsement by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

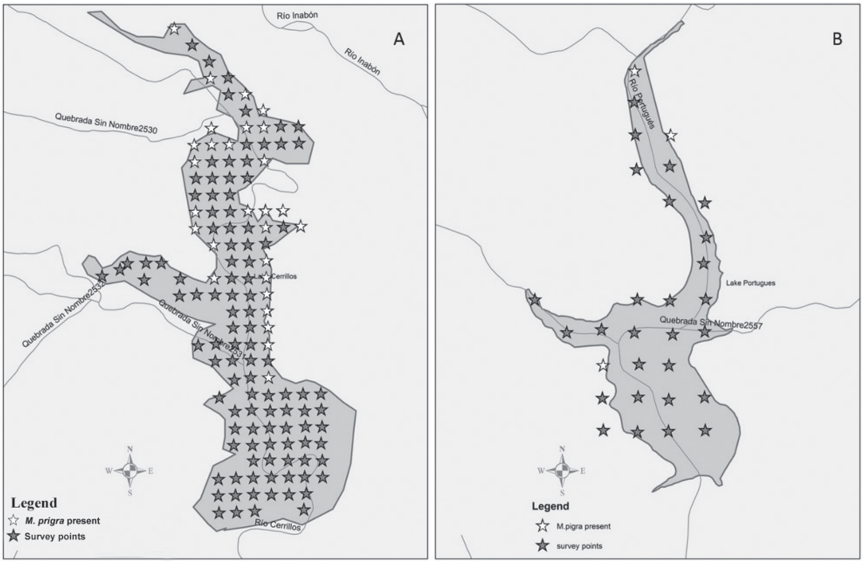

FIGURE 1. Geographic distribution of surveyed points (★) and presence of catclaw mimosa (*Mimosa pigra*) (☆) in Lake Cerrillos (A) and Lake Portugués (B).

water transparency data at each surveyed point and depth was recorded using a water depth finder. The same parameters were measured at the deepest point of each reservoir in order to describe the water column profile. This survey consisted of lowering the multiparameter probe into the water column every 30 cm up to a maximum depth of 10 m. Statistical analysis was performed using InfoStat v. 2020 software using a significance level of 0.05. Frequency of occurrence of aquatic plants was correlated to a water quality parameter measured at survey points using Spearman's correlation coefficient (r). The statistical analysis was used to determine which water quality parameter may predict aquatic plant presence.

According to the reservoir field survey performed, more than 75% of the area of both reservoirs is open water and free of aquatic vegetation. The most common aquatic plant species observed was catclaw mimosa with a frequency of occurrence of 10% and 25% at Portugués and Cerrillos reservoirs, respectively (Figure 1). Catclaw mimosa is widespread in Puerto Rico and currently listed on the Federal Noxious Weed List of the United States. This woody perennial is classified as Facultative Wetland Species (Lichvar et al., 2016) as it inhabits in wetland or non-wetland areas (Lichvar et al., 2012). Catclaw mimosa reproduces mainly by seed (Cronk and Fennessy, 2001; Langeland and Craddock-Burns, 1997) and is highly adapted to disturbance (CIEIPR, 2004) which facilitates its invasion (Center et al., 1995).

Among all water quality parameters measured, only water depth was significantly ($p < 0.05$) correlated to catclaw mimosa presence (r of -0.31 and -0.58 for Cerrillos reservoir and Portugues reservoir, respectively). This result supports field observations that catclaw mimosa was growing primarily along the shoreline, where water depth is below 5 m, and closer to boat ramps. Although catclaw mimosa can grow up to 4 m high (Lonsdale et al., 1988; Creager, 1992), it was also observed in both reservoirs, thriving under water in coves and off the shoreline. Only in the Portugués reservoir does catclaw mimosa coexist with aquatic plants from the genus *Colocasia* sp. and *Polygonum* sp.

Water quality parameters such as pH, transparency, specific conductance, total dissolved solids, dissolved oxygen and total algae are reported in Table 1 for both reservoirs. The first five parameters ranged within the same values in both reservoirs suggesting similarities between them and that they are not affected by the presence of catclaw mimosa By contrast, total algae at Portugues reservoir ranged up to 5.4 and 6.4 with or without catclaw mimosa as compared to Cerrillos reservoir that reported lower values (Table 1).

In general, the temperature throughout the water column in both lakes fluctuated between 26 and 28 °C. Data collected throughout the water column showed that dissolved oxygen in both reservoirs stratified at a water depth of 3.05 m where a decline from 8 to 1 mg/L was observed (Figure 2). Total algae in Cerrillos reservoir was relatively constant and ranged between 2 and 4 Chl µg/L throughout the water column. Portugués reservoir has similarly low values of total algae in shallow water (3 m or less); however, values increased up to 13 Chl µg/L in deeper water.

Although it is uncertain how catclaw mimosa was introduced to both reservoirs, it is suggested that disturbance events in reservoir construction, such as land alteration to construct levees that introduces soil from a different location, and further flooding promote catclaw mimosa invasion. In both reservoirs, catclaw mimosa plants were observed producing inflorescences and seedpods which means that this species is established, although its frequency of occurrence is less than 25% of the total reservoir area. This observation raises concern about further invasiveness and consequent nuisance issues related to water body management. In fact, according to Lonsdale et al. (1988) catclaw mimosa may form dense impenetrable thickets with thorny stems at plant densities as low as 0.12 plants per square meter. Moreover, once a seed germinates, plant height may increase at a rate of 2.4 to 2.6 cm per day (Creager, 1992) with a rate of spread up to 76 m per year (Lonsdale, 1993).

Management techniques need to be implemented soon in both reservoirs to prevent the spread of catclaw mimosa. Although the frequency of occurrence of catclaw mimosa is less than 25%, this seed producing species spreads rapidly. Water level fluctuations may lead to seed germination along the shoreline which promotes higher seed-bank density. Dredging operations must consider the presence of viable seed removed with the sediment to prevent the spread of catclaw mimosa.

Management tools that combine chemical and mechanical techniques are effective in limiting the spread of catclaw mimosa (Cook et al., 1996). Mechanical techniques consisting of cutting catclaw mimosa stems may be effective if plant material is removed from the

TABLE 1.—*Water quality parameters measured at surveyed points and those where catclaw mimosa was present at Cerrillos reservoir and Portugués reservoir.*

Reservoir	pH	Transparency (cm)	Specific Conductance (µS/cm)	Total Dissolved Solids (mg/L)	Dissolved Oxygen (mg/L)	Total algae (µg/L)
Catclaw mimosa not present						
Cerrillos	7.4-8.4	76-244	76-386	50-220	6.1-7.6	0.0-2.4
Portugués	8.4-8.5	91-183	319-324	208-211	7.1-7.7	1.1-6.4
Catclaw mimosa present						
Cerrillos	7.4-8.3	76-239	140-339	91-220	6.1-7.6	0.0-1.1
Portugués	8.4-8.5	91-122	319-322	208-210	7.1-7.5	1.1-5.4

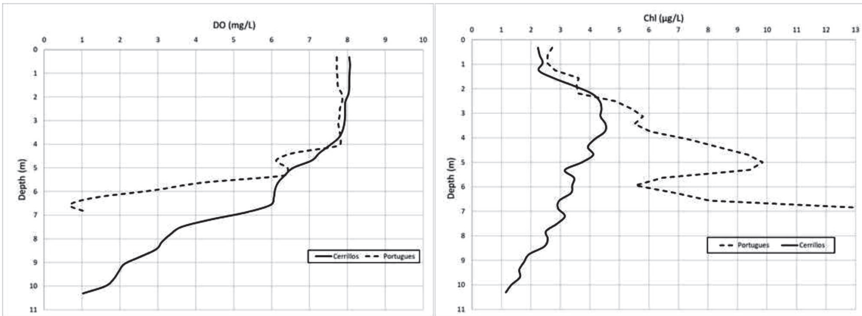

FIGURE 2. Distribution of dissolved oxygen (DO) and total algae (Chl) within the water column up to a 10-m depth of Cerrillos and Portugués reservoirs.

site to prevent seed establishment. Herbicide screening in greenhouse studies conducted in Florida have shown an acceptable efficacy of glyphosate and triclopyr in controlling catclaw mimosa (Creager, 1992). In Sri Lanka, Marambe et al. (2004) reported that glyphosate effectively controlled mimosa seedlings less than six months old, when applied three times repeatedly at four-month intervals on the same set of seedlings.

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