Best Management Practices for Cuban Bulrush (*Oxycaryum cubense*)

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Introduction and Spread

Cuban bulrush (*Oxycaryum cubense* (Poepp. & Kunth) Lye) is a monospecific epiphytic and later free-floating perennial invasive aquatic plant species native to South America (Bryson et al. 1996) that was likely introduced to Florida or Alabama from South America or the West Indies in the 1800's. Since its introduction to the U.S., Cuban bulrush has spread across the Southeastern U.S. (FL, GA, SC, AL, MS, LA, AR, and TX; Anderson 2007, Bryson et al. 1996, Lelong 1988, Thomas and Allen 1993, Tur 1971, Turner et al. 2003, and Cox et al. 2010).

The first record of Cuban bulrush in the U.S. is from 1878 from the eastern side of Mobile Bay in Alabama (SERNEC 2022); however, the species may have arrived in Florida around the same time (Chapman 1889). Cuban bulrush has also been recorded in Louisiana (first recorded in 1944), Texas (1958), Georgia (1994), and Mississippi (2001; SERNEC 2022). Cuban bulrush is also known to be in Arkansas and South Carolina but the date of first record is unknown for these states. Spread across the southern states likely occurred through plant fragments and seeds attached to boats, boat trailers, and fishing gear.

Description

There has been some confusion regarding the taxonomic classification of Cuban bulrush with various federal and state agencies referring to the species as *Oxycaryum cubense*, *Scirpus cubensis*, and/or *Cyperus blepharoleptos* (USGS 2022; USDA 2022; Godfrey and Wooten

1979). Currently, *Oxycaryum cubense* is the recognized name with *Scirpus cubensis* and *Cyperus blepharoleptos* as subordinate recognized synonyms (WFO 2022).

Cuban bulrush is a perennial plant in the sedge family (Cyperaceae; Table 1) with slender rhizomes that have a deep reddish or maroon color. Stems are slender and triangular usually less than 20 cm in length. Leaves are slender and long (can be over a meter in length at peak growth). Plants have 2 to 8 bracts (leaf like structures) at the base of each inflorescence; lowest bract will be the longest. Inflorescences can be made up of a single or multiple seed heads and are the differentiating feature among the two taxonomic forms of Cuban bulrush: the single head form is *O. cubense* forma *paraguayense* and the multiple head form is *O. cubense* forma *cubense*. Seed heads are approximately one cm in diameter and spherical in shape; the seed type is an achene.

Biology and Reproduction

Cuban bulrush is capable of sexual and asexual reproduction (Haines and Lye 1983) through achene production or vegetative fragmentation. Cuban bulrush growth from seed is as an epiphytic species on other floating plants or objects (Tur 1971; Figure 1). Individual plants will produce stolons that form a web around the initial floating object. As stolons spread, they will produce emergent shoots and submersed roots that can extend down several meters in depth. Stolons and roots will continue to intertwine and begin to trap sediment from the water column which begins the formation of a tussock (floating island). Once a plant mat has captured enough sediment from the water column in the root/stolon network the species is capable of surviving independent of other structures as a floating island or tussock (Haines and Lye 1983).

In southern Florida, growth continues year round but in northern Florida there is a noticeable decline in plant biomass in the late winter months and early spring. Seed production begins in the summer months and continues through fall. Seeds are buoyant and can remain in a tussock, float away to other sites, or land on nearby floating plant species (like water hyacinth) and be transported elsewhere. Portions of tussocks can break off, float away, and start new infestations of Cuban bulrush elsewhere. Senesced leaves (thatch) from the previous year's growth is usually present through winter into the next growing season.

Problems Associated with Cuban Bulrush

Cuban bulrush has a wide range of habitat tolerances. For example, it can grow as a free-floating plant or rooted (rarely occurs) along pond margins, it can grow in flowing or calm water, or from fresh to brackish water. Cuban bulrush can also survive and grow in cold air temperatures that cause other species to senesce each year. Because of the wide range of environmental tolerances, Cuban bulrush tussocks can be 100's of acres in size, can block boat launches and navigation lanes, block drainage canals, and degrade fishery habitat by lowering dissolved oxygen (Mallison et al. 2001). Cuban bulrush outcompetes and displaces other plant species (native and invasive) thereby disrupting ecosystem processes (Robles et al. 2007).

Management Options

The best management is prevention. The 'clean-drain-dry' and the 'stop aquatic hitchhiker' programs are educational tools that resource managers can utilize to educate their constituents on the dangers of invasive species and how to prevent their introduction or slow their spread (Anonymous 2020a, 2020b). Because human activities requiring boats have been linked to many new infestations of water bodies, it is imperative that boaters and resource managers clean plant fragments off boats, motors, jack-plates, boat trailers, fishing and hunting gear (including bait boxes, waders, and duck decoys), and out of bilge and live well water. It is best to check equipment and drain water while still on the ramp of the waterbody being exited.

If Cuban bulrush has already infested a water body, management goals (eradication vs. control) should be clearly defined so that appropriate control strategies can be implemented. Monitoring should be included in any management plan so that success or failure of control mechanisms can be assessed, and management plans can be altered if needed. Control strategies are typically divided into four categories: Biological, Mechanical, Physical, and Chemical. Biological control is the use of a living organism to reduce nuisance plant growth (i.e., grass carp). Mechanical control is done by causing physical damage to the plant (i.e., shredding). Physical control is achieved by altering the environment around the plant so that it can no longer survive (i.e., drawdown). Chemical control is the use of herbicide to kill or reduce nuisance plant growth. Integrated control is combining two or more strategies from the previous categories. The most effective control strategies "break" the life cycle of a plant so that year-to-year recruitment is reduced. For Cuban bulrush, breaking the life cycle will need to reduce seeds and vegetative propagules.

Biological – There is no known biological control agent for Cuban bulrush in the U.S. Development of biocontrol agent is unlikely in the near future due to the high cost and long time (5-10 years) needed to bring a successful biocontrol agent to operational use.

Mechanical – Shredding tussocks can work in water deeper than 1 meter but follow up visits may be needed to destroy tussock portions that re-float after the initial shredding event (J. Andreas and P. McCord, personal communication). Resource managers should carefully assess the use of shredding as this activity may produce vegetative fragments that can drift to new sites and make an infestation in a waterbody worse over time. Shredding as a follow up to chemical control may be a suitable integrated control technique; however, Cuban bulrush seeds may still be present that could survive both management activities.

Physical – Drawdown is unlikely to work as seeds can persist and re-establish when water returns to the site. However, prescribed fire may be useful as part of an integrated technique to reduce dead Cuban bulrush thatch from previous years so that herbicide contact, and thus uptake, by leaves is increased (Turnage, Unpub. data).

Chemical – To date, herbicides have been the most studied and used control option for reducing Cuban bulrush growth. There are 15 herbicides labeled for general aquatic use in the United States which is a fraction of those labeled for terrestrial use (approximately 300). Peroxides and dyes are also chemicals labeled for control of aquatic plants and algae, but they do not affect plants in the same manner as herbicides. These 15 herbicides fall in nine different herbicide modes of action: auxin mimic (2,4-D, florpyrauxifen-benzyl, and triclopyr), ALS inhibition (bispyribac-sodium, imazamox, imazapyr, and penoxsulam), PPO inhibition (flumioxazin and carfentrazone-ethyl), EPSP inhibition (glyphosate), PS 1 electron diversion (diquat), PDS inhibition (fluridone), HPPD inhibition (topramezone), STP inhibition (endothall), and one unknown mode of action (copper).

Much of the work regarding chemical control of Cuban bulrush has been done in mesocosms (livestock tanks) and focused on foliar applications of single herbicides (Watson and Madsen 2014; Turnage 2020, 2021; Turnage and McLeod 2021) with a few studies focused on foliar applied herbicide combinations (Turnage 2021; Turnage and McLeod 2021) or submersed herbicide applications (Turnage 2018, Turnage Unpub. data).

The first work to document control of Cuban bulrush was Watson and Madsen (2014) in which 10 of the 15 herbicides labeled for general aquatic use were tested at the maximum label rates (except flumioxazin [1/10 label rate]) for control of the plant in a mesocosm setting (Table 2). Watson and Madsen (2014) found that every herbicide tested reduced Cuban bulrush >85% if applied pre-flowering but that post-flowering flumioxazin, glyphosate, 2,4-D, triclopyr, and diquat were the most effective (>85% control; Table 2). Turnage (2021a) found that reduced rates of 2,4-D, triclopyr, and diquat (1/4 max label rate) provided 99% control of Cuban bulrush 52 weeks after treatment (WAT; Table 2). Turnage and McLeod (2021) found that florpyrauxifen-benzyl provided >90% reduction of Cuban bulrush 52 WAT (Table 2). Turnage (2021b) found that triclopyr, diquat, and florpyrauxifen-benzyl reduced Cuban bulrush >85, 81, and 70% 8 WAT at field sites across the state of Florida (Table 2). Turnage (2021b) also noted that Cuban bulrush tussocks treated with triclopyr were reverting to open water while the underlying tussock still remained in sites treated with diquat or florpyrauxifen-benzyl.

Foliar applications of a few herbicide tank-mixes have also been assessed (Table 3). Turnage and McLeod (2021) assessed combinations florpyrauxifen-benzyl mixed with flumioxazin or penoxsulam and found >98% biomass reduction of Cuban bulrush 52 WAT (Table 3). Turnage (2021) found that glyphosate + flumioxazin provided >72% Cuban bulrush biomass reduction 8 WAT in field sites (Table 3).

Submersed herbicide applications are another option that may be useful for Cuban bulrush control. However, resource managers should carefully assess water exchange rates of infested sites with rhodamine dye studies to determine if herbicide residues will remain in contact with target plants for a sufficient amount of time to control plants. Turnage (2018) found that submersed static applications of carfentrazone-ethyl, flumioxazin, fluridone, and triclopyr reduced Cuban bulrush biomass 98, 93, 94, and 100% (respectively) 52 WAT (Table 4). Control increased to 100% when mixing fluridone with either carfentrazone-ethyl or flumioxazin and was 98 to 100% when mixing triclopyr with either of the PPO inhibiting herbicides (Turnage 2018). Turnage (2018) noted that submersed herbicide treatments selectively controlled Cuban bulrush growing with softstem bulrush (*Schoenoplectus tabernaemontani*) and cattail (*Typha* spp.). Static exposures of 2,4-D reduced Cuban bulrush biomass >73% 52 WAT (Turnage, Unpub. Data).

Integrated Control – Very little work has been done in this area for Cuban bulrush, but integrated techniques can often be more cost effective than stand-alone control techniques due to the compounding effects of multiple stressors on the target plant. For example, in a mesocosm study, Turnage (Unpub data) found that conducting spring season prescribed fire followed by early summer foliar herbicide application (1.68 kg ai/ha triclopyr) provided 100% Cuban bulrush biomass reduction in mesocosms compared to no reduction by fire alone or 74% biomass reduction by herbicide alone. The increased biomass reduction was likely due to thatch removal by fire and therefore better herbicide to leaf contact by the later herbicide treatment; this technique should be validated in field sites prior to recommendation for operational use. Care should be taken to ensure proper fire lanes or containment barriers are in place prior to the use of prescribed fire, but the ease of implementation and relatively low cost compared to other control strategies make prescribed fire a useful control strategy for Cuban bulrush management.

Summary

Long term Cuban bulrush management should focus on breaking the life cycle of the plant by reducing seed production and vegetative propagules. This can be achieved by implementing management strategies that control vegetative growth prior to seed head formation in early summer. Resource managers should establish clear benchmarks for success prior to selecting and implementing management strategies to control Cuban bulrush. Monitoring and data collection (stem and inflorescence density, plant height, and percent cover) should be a key aspect of any management plan so that success or failure of control strategies can be determined and allow resource managers to switch strategies if needed. Most herbicides will control Cuban bulrush pre-flowering; however, flowering may be hard to detect as it occurs soon after sprouting and may not be evident due to the previous year's thatch blocking visibility. Post-flowering, glyphosate, diquat, PPO inhibitors, and auxinic herbicides can be used to control Cuban bulrush but most herbicides that control Cuban bulrush do not destroy the underlying sediment layer of the tussock so re-colonization of previously managed sites may occur. Triclopyr applications are the exception to this as treated sites begin to revert to open water in a matter of weeks.

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Tables and Figures

Table 1. Taxonomy of Cuban bulrush.

KINGDOM	Plantae
DIVISION	Magnoliophyta
CLASS	Liliopsida
ORDER	Cyperales
FAMILY	Cyperaceae (Sedges – Includes Oxycaryum, Scirpus, and Cyperus)
GENUS	Oxycaryum
SPECIES	*Oxycaryum cubense*

Table 2. Herbicides labeled for aquatic use that have been tested for control of Cuban bulrush, foliar application rate, and source; in the Rate column, the lowest rate tested in each source that delivered effective control was reported; in the Efficacy and Sources column, the order of corresponds to rates tested in Rate column; in the Efficacy column, WAT = weeks after treatment, pre or post refer to pre-flowering or post-flowering, and percentages separated by a comma come from the same source and those separated by semi-colons are from different sources; in the Source column, M = mesocosm experiment and F = field experiment.

Herbicide	Rate	Efficacy	Source (M/F)
2,4-D	4.26 kg ae/ha; 1.06 kg ai/ha	>85% 8 WAT (pre); >99% 52 WAT	Watson and Madsen 2014 (M); Turnage 2020 (M)
Bispyribac-sodium	0.448 kg ai/ha	>85% 8 WAT (pre)	Watson and Madsen 2014 (M)
Carfentrazone-ethyl	0.22 kg ai/ha	>85% 8 WAT (pre)	Watson and Madsen 2014 (M)
Diquat	4.48 kg ai/ha; 1.11 kg ai/ha	>85% 8 WAT (pre), >85% 6 WAT (post); >99% 52 WAT; >81% 8 WAT	Watson and Madsen 2014 (M); Turnage 2020 (M); Turnage 2021 (F)
Florpyrauxifen-benzyl	0.03 kg ai/ha	>90% 52 WAT; >70% 8 WAT	Turnage and McLeod 2021 (M); Turnage 2021 (F)
Flumioxazin	0.042 kg ai/ha	>85% 8 WAT (pre)	Watson and Madsen 2014 (M)
Glyphosate	4.54 kg ae/ha	>85% 8 WAT (pre), >85% 6 WAT (post)	Watson and Madsen 2014 (M)
Imazamox	0.56 kg ai/ha	>85% 8 WAT (pre)	Watson and Madsen 2014 (M)
Imazapyr	1.68 kg ai/ha	>85% 8 WAT (pre)	Watson and Madsen 2014 (M)
Penoxsulam	0.10 kg ai/ha	>85% 8 WAT (pre)	Watson and Madsen 2014 (M)
Triclopyr	6.72 kg ae/ha; 5.04 kg ai/ha; 5.04 kg ai/ha	>85% 8 WAT (pre), >85% 6 WAT (post); >99% 52 WAT; >85% 8 WAT	Watson and Madsen 2014 (M); Turnage 2020 (M); Turnage 2021 (F)

Table 3. Herbicide tank-mixes for foliar application that have been tested for control of Cuban bulrush, application rate, and source; in the Rate column, the lowest rate tested in each source that delivered effective control was reported; in the Efficacy and Sources column, the order of corresponds to rates tested in Rate column; in the Efficacy column, WAT = weeks after treatment and percentages separated by a comma come from the same source and those separated by semi-colons are from different sources; in the Source column, M = mesocosm experiment and F = field experiment.

Herbicide	Rate	Efficacy	Source (M/F)
Florpyrauxifen-benzyl + Penoxsulam	0.03 + 0.05 kg ai/ha	>98% 52 WAT	Turnage and McLeod 2021 (M)
Florpyrauxifen-benzyl + Flumioxazin	0.03 + 0.21 kg ai/ha	>99% 52 WAT	Turnage and McLeod 2021 (M)
Glyphosate + Flumioxazin	6.05 + 0.105 kg ai/ha	>72% 8 WAT	Turnage 2021 (F)

Table 4. Submersed herbicides and application rates investigated for control of Cuban bulrush; in the Rate column, concentrations were applied as static exposures; in the Efficacy column, WAT = weeks after treatment; in the Source column, M = mesocosm experiment and F = field experiment.

Herbicide	Rate	Efficacy	Source (M/F)
2,4-D	4.0 ppm	>73% 52 WAT	Turnage (Unpub. Data; M)
Carfentrazone-ethyl	0.1 ppm	>98% 52 WAT	Turnage 2018 (M)
Flumioxazin	0.2 ppm	>93% 52 WAT	Turnage 2018 (M)
Fluridone	0.01 ppm	>94% 52 WAT	Turnage 2018 (M)
Triclopyr	0.75 ppm	100% 52 WAT	Turnage 2018 (M)
Flur + Carf	0.01 + 0.1 ppm	100% 52 WAT	Turnage 2018 (M)
Flur + Flum	0.01 + 0.2 ppm	100% 52 WAT	Turnage 2018 (M)
Tri + Carf	0.75 + 0.1 ppm	100% 52 WAT	Turnage 2018 (M)
Tri + Flum	0.75 + 0.2 ppm	>97% 52 WAT	Turnage 2018 (M)

Figure 1. Cuban bulrush growing from a water hyacinth rosette (left) and atop a giant salvinia mat (right); photos by G. Turnage.

Figure 2. Cuban bulrush tussock covering 100’s of acres on Orange Lake, Florida; photo by G. Turnage.

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