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Foliar herbivory and infestation characteristics of invasive crested floating heart in the southern United States

NATHAN E. HARMS, MEGANN M. HARLOW, AND CORRINA VUILLEQUEZ*

ABSTRACT

The invasive aquatic plant *Nymphoides cristata* (crested floating heart) is widespread and damaging in southeastern U.S. waterbodies, but infestations have not been characterized or assessed for herbivory to inform management. We combined field surveys and a simulated herbivory experiment to evaluate the potential role of herbivory for control of crested floating heart. We surveyed 15 crested floating heart populations in four states to quantify population and plant-level characteristics and foliar herbivory *in situ*. In a controlled outdoor mesocosm experiment we subjected crested floating heart plants to a range of simulated herbivory treatments (0, 10, 50, and 75% damage), then measured growth and reproductive response. Crested floating heart dominance *in situ* ranged from 0.87 to 1.0, and flower production was high (up to 618/m^2). Leaf area consumed by herbivores ranged from 0 to 42%, and we detected six herbivore taxa, most of which were generalist species such as aquatic moths and leaf beetles. We did not find strong correlations between population or leaf characteristics and percent leaf damage, but leaf toughness was correlated with other traits related to herbivory, including percent nitrogen, carbon : nitrogen ratio, dry mass content, and specific leaf area. Simulated herbivory produced only minor differences between treatments, suggesting that even high levels of transient foliar herbivory may be insufficient to limit the spread of crested floating heart. This information can be used to assess potential benefits, interactions, and management synergies with biological control of crested floating heart, should it be pursued.

Key words: biological control, floating-leaved invader, *Nymphoides cristata*, simulated herbivory.

INTRODUCTION

Nymphoides cristata (Roxb.) Kuntze (crested floating heart) is an invasive floating-leaved aquatic plant that is native to Southeast Asia and introduced into the United States. First detected in a residential water body in 1996 near Naples, FL, the population expanded and spread via canals, watercraft, and connected waterways to lakes more than 160 km away (Burks 2002). In 2006 a population of crested floating heart was documented in Lake Marion, SC, and by 2012 it infested approximately 2,400 ha, despite herbicide applications, water drawdowns, and harsh winter freezes (Westbrooks et al. 2013). Since that time, new populations have been detected in Louisiana (2012), North Carolina (2014), Texas (2015), and Mississippi (2016) (EDDMapS 2021, Thayer and Pfingsten 2021). The scattered distribution of crested floating heart populations across the region and recent genetic evidence suggests multiple introductions (Burks 2002, Kuzniar et al. 2024).

There are seven *Nymphoides* species present in the United States (four native and three non-native), all of which have the nymphaeid growth form (Tippery and Les 2011, Tippery et al. 2018). All *Nymphoides* spp. are rooted in the substrate with the stem extending upward to heart-shaped floating leaves and small flowers held above the water surface. Crested floating heart differs from its congeners by producing white flowers with petals crested down the midline (Gettys et al. 2017, Willey and Langeland 2018). Dense infestations result in overlapping of the floating leaves, which can obstruct water flow, limit recreational access, reduce dissolved oxygen, and outcompete native plants for light, space, and nutrients (Gettys et al. 2017, Willey and Langeland 2018).

The ability for crested floating heart to rapidly spread and colonize vegetatively (i.e., via stolons, rhizomes, and ramets) has contributed to its listing as a Category I (i.e., the species has demonstrated ecological damage) invasive species by the Florida Exotic Plant Pest Council (FLEPPC 2019). By 2014 Florida added crested floating heart to the state Noxious Weed List (FDACS 2020). Furthermore, the United States Department of Agriculture (USDA) has declared the plant to be a "High Risk" weed based on its ability to spread rapidly and negatively impact native habitat (USDA 2012). There is substantial concern about hybridization between invasive and native *Nymphoides* spp. and the implications that has for controlling infestations. One such case of hybridization between crested floating heart and the native *Nymphoides aquatica* (J. F. Gmel.) Kuntze has already been detected in Lake Moultrie, SC (Harms et al. 2021).

Typical management strategies for aquatic weeds include the use, or combination, of mechanical removal, herbicide application, and biological control. Mechanical removal is not ideal for crested floating heart, as the costly process leaves behind plant fragments that allow the population to regrow and/or spread (Burks 2002). Shortly after introduction into the United States, studies found that crested floating

*First and second authors: Research Biologists, U.S. Army Engineer Research and Development Center, Lewisville, TX 75057. Third author, graduate student, University of Florida, Department of Agronomy, Gainesville, FL 32653. Corresponding author's E-mail: Nathan.E.Harms@usace.army.mil. Received for publication March 23, 2026 and in revised form June 12, 2026.

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heart showed broad tolerance to most commonly used herbicides (Willey 2012, Willey et al. 2014, Glomski and Netherland 2016, Willey and Langeland 2018). However, herbicide development to manage *Nymphoides* spp. in recent years has shown promising options, including florpyrauxin-benzyl (ProcellaCOR; an auxin mimic herbicide) and endothall (a dipotassium salt) (Netherland and Richardson 2016, Beets and Netherland 2018, Mudge and Netherland 2020). Biological control options are not available for crested floating heart as of 2026 but are being considered (Harms and Nachtrieb 2019).

Baseline ecological information about a new invader is essential to measure effective management. Records of geographic distribution (Burks 2002, EDDMapS 2021), population and plant-level characteristics, and current patterns of herbivory (Harms and Grodowitz 2009) can provide support to biological control development and implementation. To achieve this in relation to the invasion of crested floating heart into the southeastern United States, we surveyed 15 crested floating heart populations across Florida, Texas, Louisiana, and South Carolina in 2019. We quantified a range of plant-level and, in a subset of populations, population-level characteristics. We additionally conducted a mesocosm-based simulated herbivory experiment to determine how varying levels of foliar herbivory impact crested floating heart growth and reproduction. This is the first characterization of crested floating heart across the invaded U.S. range and the first attempt to determine how herbivory may be used to limit its spread or reduce its abundance, as would be the objective in future biological control programs.

MATERIALS AND METHODS

Field surveys

During August 2019, 15 sites across four states were visited to assess crested floating heart plant- and population-level characteristics (Figure 1). At each visited crested floating heart population, we randomly placed six 0.1 m^2 quadrats within the infestation, then measured water depth in the center of the quadrat and its distance from shore. The number of flowers within the quadrat was counted. Percent cover of crested floating heart within the quadrat and percent total (all plants) cover were estimated to calculate a dominance index (DI; percent crested floating heart/percent total cover). DI values could range from 0 to 1, and a DI near 1 would indicate that crested floating heart was dominant (i.e., made up a large proportion of the total cover) in a location.

At each site, six crested floating heart plants were randomly sampled, and leaves were excised and placed on a white background with a ruler for scale, then photographed to estimate percent herbivory and leaf area. Images were processed using ImageJ image software (Rasband 2014), and percent leaf damage was calculated as

$$\text{Percent leaf damage} = (1\text{–}[\text{damaged leaf area}/\text{whole leaf area}] \times 100).$$

To evaluate possible relationships between leaf traits and herbivory, a number of leaf characteristics were determined. Leaf toughness was measured on the same six photographed fresh leaves with a force gauge,[1] twice on each leaf by placing the leaf on a round PVC surface with a 10 mm hole, then pressing a 9 mm cylindrical rod through the leaf. Leaves were then weighed before and after drying in silica gel. Dry weight and leaf area were used to calculate dry mass content (DMC: dry weight/fresh weight) and specific leaf area (SLA: leaf area/dry weight). Tissue chemistry analyses were performed on dry leaves at the Louisiana State University Agricultural Chemistry Laboratory, Baton Rouge, LA. Percent leaf carbon and nitrogen were determined with the modified Dumas method, and percent tissue phosphorus was determined with inductively coupled plasma mass spectrometry (Jones and Case 1990).

Simulated herbivory

To evaluate the tolerance of crested floating heart to herbivory, we conducted a simulated herbivory experiment in outdoor mesocosms at the University of Florida, Gainesville, FL (29.72°N; 82.42°W) in summer 2025. We used crested floating heart plants from long-term culture that were originally collected from stormwater treatment areas in south Florida (26.67°N; 80.35°W) in 2022. We used 2-L pots filled with sand amended with time-release fertilizer (15-9-12 N : P : K)[2] at 4 g L^{-1} and covered with an unfertilized 2 cm cap of sand to reduce nutrient resuspension. Five sprouted ramets (propagules with both roots and leaves) were planted per pot, and each pot was placed into a 20-L plastic bucket filled with well water. Buckets were wrapped in reflective insulation to moderate temperature swings and then placed outdoors in the open on black weed barrier cloth for the duration of the experiment. Ten weeks after planting, herbivory treatments were applied. At the time of treatment, all mesocosms had their surface area completely covered with crested floating heart leaves. Plants were subjected to either 0% (control), 10, 50, or 75% herbivory. The study had a completely randomized design with 10 replications per treatment. Herbivory treatments were initially applied over the course of 1 wk, then reapplied to new leaves every 2 wk thereafter. Thus, containers received three total simulated-herbivory treatments. Herbivory was simulated by cutting leaves with scissors, such that the percent damage treatment reflected the amount of each leaf that was removed from the container. Treatments were applied to new leaves, not to leaves that were treated during the previous period. The levels of herbivory treatments were chosen to include levels observed in the field (see below). Throughout the experiment, the plants were routinely treated with a rotation of carbaryl[3] and bifenthrin[4] to prevent insect damage.

Three weeks after the third treatment, we harvested all plants. During harvest, five leaves per replicate were randomly chosen, individually weighed, then imaged on a white background with a ruler for scale. Above and belowground crested floating heart biomass were separated and rinsed, then dried in a forced air oven at 70 C and weighed to the nearest 0.01 g. Individual weights of the five imaged leaves were included in the overall aboveground biomass calculation. Leaf images were processed with ImageJ image analysis software, as above, to determine leaf area. Fresh and dry leaf weights and area were used to calculate leaf dry mass content (DMC: dry leaf weight [g]/fresh leaf weight [g]) and

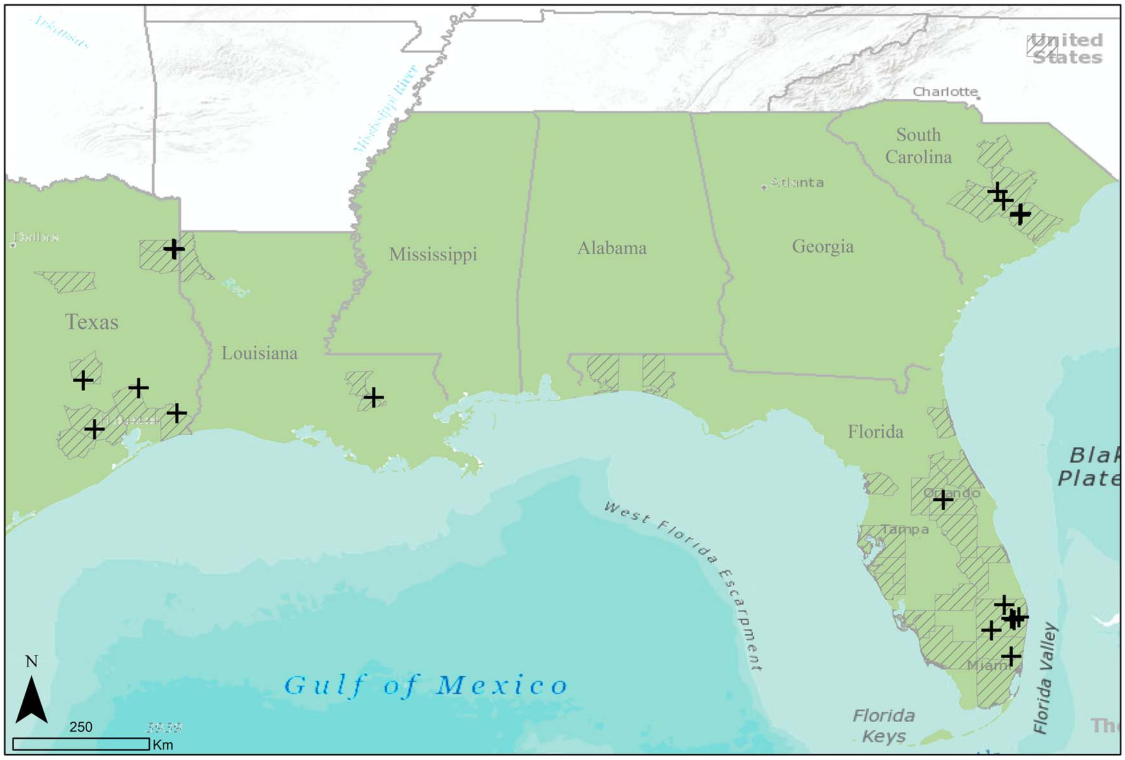

Figure 1. Locations in the southeastern United States where crested floating heart was evaluated for herbivory and population characteristics.

specific leaf area (SLA: leaf area [mm^2]/dry weight [mg]) for each leaf. After weighing, leaves for each replicate were pooled and processed for carbon/nitrogen analysis. Percent leaf carbon and nitrogen were determined with the modified Dumas method (Jones and Case 1990) in the Biological Control Laboratory at the U.S. Army Engineer Research Development Center, Vicksburg, MS.

Statistical approach

For field surveys, summary statistics (mean ± SE, minimum and maximum) were calculated for all measured variables. In addition, Pearson's correlation was used to evaluate relationships among site characteristics (water depth, distance from shore, crested floating heart dominance), leaf traits (percent nitrogen, percent carbon, percent phosphorus, carbon : nitrogen ratio, leaf toughness, specific leaf area, dry matter content), and herbivory (percent leaf damage). Statistics from field surveys were calculated with JASP[5].

To compare simulated herbivory treatments in the mesocosm experiment, total biomass, biomass allocation (shoot : root ratio), DMC, and SLA were calculated for each plant. One-way ANOVA was used to compare treatment levels at $\alpha = 0.05$, and Tukey's *post-hoc* test was used to separate statistically different means. Statistics from the simulated herbivory experiment were calculated in SAS v9.4 (SAS Institute Inc., Cary, NC).

RESULTS AND DISCUSSION

Crested floating heart was a dominant species in the populations that we surveyed (Table 1; dominance index: 0.96 ± 0.04). Flowering was estimated to be as high as 618 ± 61.8 flowers/m^2 (Lake Marion, SC) and averaged 355 ± 55 flowers/m^2 across sites.

In situ herbivory

Although most (89%) analyzed leaves had signs of herbivory, damage levels were low, with a mean 4.1 ± 0.8% foliar damage across sites (range: 0.53 ± 0.18 to 8.73 ± 6.80% damage; Table 2). The FM 787 pond in Texas and JW Corbett Wildlife Management Area in Florida had the highest levels of herbivory at 8.73 ± 6.80% and 8.69 ± 5.75% leaf damage, respectively. Levels of foliar feeding by native or introduced insects has been documented for several aquatic plant species in the United States previously. Feeding by native herbivores on the introduced aquatic weed *Ludwigia hexapetela* (Hook & Arn.) Zardini, H. Y. Gu, & P. H. Raven (Uruguayan primrose-willow; Onagraceae) in Alabama was similarly low (maximum 14%), and not enough to contain the growth and spread of the plant there (Harms et al. 2017). In contrast, foliar damage associated with feeding by a biological control agent of the invasive *Alternanthera philoxeroides* (Mart.) Griseb. (alligatorweed; Amaranthaceae) in Louisiana varied from low (average of 7%) in northern Louisiana sites where control is poor to moderate or high (average 21%, seasonal peak of 60 to 80%) in southern Louisiana where control is considered good (Harms and Shearer 2017). Thus, the levels of damage documented on crested floating heart in the field, although they represent only a snapshot in time, are likely insufficient to slow the spread and creep of crested floating heart in and between waterbodies.

Table 1. Descriptive statistics (mean ± standard error) for crested floating heart demography at all sites. Overall means for each variable is reported at the bottom of each column. +Results reported for composite samples.

Site Name	Latitude; Longitude	Dominance Index	No. of Flowers/m^2	Water Depth (cm)	Distance to Shore (m)	Total Leaf Area (mm^2)
Florida						
JW Corbett WMA	26.86N; 80.42W	—	—	—	—	372.9 ± 100.8
Lake breeze DR	28.60N; 81.42W	0.93 ± 0.07	402 ± 157.0	32.6 ± 3.2	7.8 ± 2.1	693.3 ± 82.9
Pembroke Pines	26.01N; 80.30W	—	—	—	—	890.9 ± 294.3
Site 15	26.65N; 80.17W	0.99 ± 0.01	378 ± 79.5	56 ± 6.0	378 ± 79.5	513.8 ± 120.4
Sta 1	26.44N; 80.63W	1.00 ± 0.00	72.5 ± 20.2	43.8 ± 2.4	72.5 ± 20.2	391.0 ± 86.8
Wellington	26.61N; 80.25W	1.00 ± 0.00	338 ± 29.7	97 ± 3.0	5.0 ± 0.3	549.7 ± 72.3
Louisiana						
Martin lake	30.29N; 90.83W	0.96 ± 0.03	486 ± 61.9	82 ± 7.2	15.4 ± 5.2	769.0 ± 207.9
South Carolina						
Lake Marion	33.54N; 80.43W	1.00 ± 0.00	618 ± 61.8	118.6 ± 10.9	35 ± 12.7	763.3 ± 191.5
Lake Moultrie	33.29N; 80.16W	0.96 ± 0.05	155 ± 25.0	130 ± 50.0	12.5 ± 2.5	665.4 ± 160.3
Texas						
Caddo Lake site 1	32.73N; 94.12W	0.97 ± 0.02	430 ± 41.2	73 ± 6.4	38 ± 7.3	598.5 ± 198.0
Caddo Lake site 2	32.74N; 94.15W	0.95 ± 0.04	508 ± 76.9	70 ± 4.5	3.4 ± 0.5	748.5 ± 184.3
FM 787	30.44N; 94.72W	—	—	—	—	471.8 ± 124.7
Houston Arboretum	29.76N; 95.45W	0.87 ± 0.06	164 ± 56.8	38 ± 5.8	1.3 ± 3.0	568.6 ± 49.8
Lake Conroe	40.56N; 95.64W	—	—	—	—	301.8 ± 76.8
Port Arthur RD	30.03N; 94.09W	—	—	—	—	411.8 ± 88.0
Overall means	—	0.96 ± 0.04	355 ± 55.2	74 ± 33	57 ± 36.4	580.7 ± 44.5

Levels of herbivory were not correlated with plant variables during the survey. However, several leaf traits related to herbivory were correlated with each other. Specific leaf area was negatively correlated with depth ($r = -0.748$, $P = 0.013$), leaf toughness (-0.535, $P = 0.04$), and dry matter content ($r = -0.807$, $P = 0.009$). Leaf toughness was negatively correlated with % leaf N ($r = 0.659$, $P = 0.008$) and positively correlated with C : N ratio ($r = 0.746$, $P = 0.001$). Relationships between structural and chemical leaf traits are common, making up a suite of traits that relate to herbivory and herbivory defenses in aquatic plants (e.g., Gross and Bakker 2012, Grutters et al. 2016). For example, leaf toughness is typically negatively associated with growth rate (i.e., fast growing plants have tender leaves) and positively related with C : N ratio. Foliar nitrogen is positively associated with performance for many herbivores (Grutters et al. 2016). Likewise, dry matter content is known to be highly correlated with toughness, as it describes an aspect of leaf density, with denser leaves typically being less palatable to herbivores (Elger and Willby 2003, Kitajima and Poorter 2010). Mean percent leaf N (3.25 ± 0.16%) across sites was slightly lower than that documented for alligatorweed (4 to

Table 2. Descriptive statistics (mean ± standard error) for crested floating heart leaf characteristics at all sites. Overall means for each variable is reported at the bottom of each column. +Results reported for composite samples. dmc = dry mass content, dw = dry weight, fw = fresh weight, sla = specific leaf area, %c = percent carbon, %n = percent nitrogen, %p = percent phosphorus, c : n = carbon : nitrogen ratio.

Site	% Leaf Damage	DMC (G DW/G FW)	Leaf Toughness (KG)	SLA (MM^2/MG)	%C+	%N+	C : N Ratio+	%P+
Florida								
JW Corbett wma	8.69 ± 5.75	—	0.23 ± 0.06	3.78 ± 0.35	42.39	3.10	13.69	0.25
Lake breeze DR	4.35 ± 2.31	—	0.18 ± 0.06	3.80 ± 0.18	42.05	3.32	12.66	0.46
Pembroke Pines	2.43 ± 0.90	—	0.25 ± 0.04	6.89 ± 1.68	42.52	2.61	16.30	0.17
Site 15	2.98 ± 1.31	—	0.22 ± 0.07	3.70 ± 0.19	40.66	3.09	13.15	0.27
Sta 1	2.13 ± 1.06	—	0.26 ± 0.08	2.68 ± 0.15	40.61	3.41	11.91	0.38
Wellington	3.04 ± 1.41	—	0.30 ± 0.06	2.63 ± 0.15	40.96	2.43	16.84	0.14
Louisiana								
Martin lake	4.94 ± 2.02	0.102 ± 0.005	0.24 ± 0.06	3.34 ± 0.22	41.27	2.69	15.32	0.57
South Carolina								
Lake Marion	4.69 ± 2.40	0.126 ± 0.014	0.32 ± 0.04	2.51 ± 0.34	42.91	2.74	15.67	0.48
Lake Moultrie	2.07 ± 1.05	0.153 ± 0.018	0.53 ± 0.16	1.98 ± 0.14	42.75	2.36	18.10	0.32
Texas								
Caddo Lake site 1	2.65 ± 1.17	0.097 ± 0.005	0.13 ± 0.03	3.94 ± 0.31	40.65	4.08	9.95	0.57
Caddo Lake site 2	0.53 ± 0.18	0.071 ± 0.006	0.16 ± 0.03	3.82 ± 0.19	42.03	3.83	10.99	0.59
FM 787	8.73 ± 6.80	0.082 ± 0.011	0.14 ± 0.06	5.13 ± 0.93	42.80	3.23	13.25	0.27
Houston Arboretum	5.73 ± 4.37	0.099 ± 0.002	0.27 ± 0.03	4.17 ± 0.41	43.06	3.93	10.96	0.32
Lake Conroe	7.23 ± 2.89	0.113 ± 0.009	0.16 ± 0.06	3.94 ± 0.44	42.16	3.62	11.65	0.66
Port Arthur RD	1.87 ± 0.88	0.099 ± 0.005	0.18 ± 0.05	4.50 ± 0.30	43.23	4.30	10.04	0.51
Overall Means	4.1 ± 0.80	0.105 ± 0.008	0.24 ± 0.11	3.79 ± 0.38	42 ± 0.24	3.25 ± 0.16	13.4 ± 0.66	0.40 ± 0.04

Table 3. Herbivore taxa recovered from crested floating heart during surveys in the southeastern United States. a = adult, p = pupa, l = Larva.

Site	Life Stage	Count	Order	Family	Genus	Species
Florida						
Site 15	L	2	Lepidoptera	Crambidae	*Elophila* (= *synclita*) prob. *obliteralis*	
Sta 1	L	4	Lepidoptera	Crambidae	*Elophila* (= *synclita*) prob. *obliteralis*	
Louisiana						
Martin lake	A	1	Coleoptera	Chrysomelidae	*Donacia* sp.	
	A	2	Lepidoptera			
	P	1	Coleoptera	Coccinellidae		
Texas						
Houston arboretum	A	3	Coleoptera	Curculionidae	*Onychylis*	*nigrirostris*

8%), but within the range of flowering rush (*Butomus umbellatus* L.) (2 to 5%) and other macrophytes (approximately 1.5 to 5%) (Lodge 1991, Duarte 1992, Grutters et al. 2016, Harms and Cronin 2019, Harms and Walter 2021).

Although not the primary focus of our study, herbivores were encountered during examination of crested floating heart plants during surveys and represent new host records (Table 3). Three herbivore taxa were recovered from four sites, including larval *Elophila* (= *Synclita*) *obliteralis* Walker (Lepidoptera: Crambidae), adult *Onychylis nigrirostrus* LeConte (Coleoptera: Curculionidae), and *Donacia* sp. (Coleoptera: Chrysomelidae). *Elophila obliteralis* was previously reported from *N. aquatica* (J. F. Gmel.) Kuntze in South Carolina (Stoops et al. 1998). *Elophila obliteralis* is a generalist aquatic caterpillar, known to feed on more than 60 aquatic host species (Habeck and Cuda 2009, Harms and Grodowitz 2009). *Onychylis nigrirostris* was detected at only a single site in Texas, but its distinctive feeding damage was apparent there (for a description, see Center 2002). This species is known to feed on at least four aquatic plant species, including *Nuphar lutea* ssp. *advena* (Aiton) Kartesz & Gandhi, *Nymphaea odorata* Aiton, *Pontederia cordata* L., and *Sagittaria* sp. (Tanner 1943, McGaha 1952, Center 2002). Although adult *O. nigrirostris* feeding has been documented on a number of plants, it has been speculated that only *P. cordata* is a larval host (Center 2002). We were unable to obtain an identity of the lone *Donacia* sp. in our collections, though *Donacia* were commonly observed at field sites (pers. obs.). *Donacia* are herbivores of aquatic plants, with many different host associations, depending on the species (Harms and Grodowitz 2009). Although many *Donacia* spp. have been documented to feed on multiple species, there is a question about whether some are specialized on a single type or taxa of plant (Cronin et al. 1998).

Simulated herbivory

Despite simulated herbivory levels as high as 75%, crested floating heart plants were resilient to damage. There were slight indications of herbivory effects across measured variables but few clear differences. Flowering did not differ among treatments (df = 3, F = 1.3, P = 0.28), ranging from 38 ± 1.36 flowers in the 75% herbivory treatment to 45 ± 1.91 flowers in the 10% herbivory treatment. Biomass allocation (shoot : root ratio) similarly did not vary with herbivory treatment (df = 3, F = 1.5, P = 0.22), ranging from 2.92 ± 0.28 (75%) to 3.81 ± 0.32 (0%). Total biomass (dry weight) was influenced by simulated herbivory treatments (df = 3, F = 4.2, P = 0.012; Figure 2), but there was only a 14% difference in dry biomass between the control 0% herbivory treatment (45.29 ± 1.42 g) and the 75% herbivory treatment (39.43 ± 0.99 g). Neither leaf variable was significantly different among treatments (DMC: df = 3, F = 0.9, P = 0.45; SLA: df = 3, F = 0.3, P = 0.81). We similarly found no differences in percent leaf carbon (df = 3, F = 0.23, P = 0.87) or nitrogen (df = 3, F = 0.37, P = 0.78) between simulated herbivory treatments.

Crested floating heart is a widespread invasive plant in the southeastern United States, with most infestations concentrated in Texas and Florida (EDDMapS 2021). We found that in locations where crested floating heart occurs, it often has high dominance and is associated with shallow (< 1.5 m) waterbodies, where it flowers prolifically. Levels of foliar herbivory *in situ* are low, as would be expected for a successful and abundant invader. Despite applying high levels of mechanical damage to simulate herbivory in a controlled mesocosm study, crested floating heart biomass was reduced only slightly from the control and did not differ from 10 to 75% leaf damage. This represents a first step in evaluating the types and magnitude of herbivory that may be useful as a

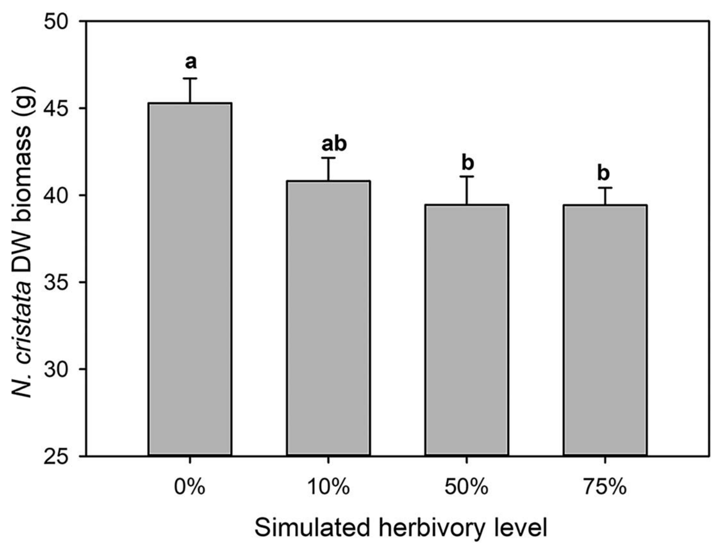

Figure 2. Dry weight (mean ± SE) final biomass of crested floating heart exposed to various simulated herbivory treatments. Letters denote statistical differences in treatment means, determined by Tukey's *post-hoc* test (α = 0.05).

management tool. Furthermore, these findings provide direction for additional research. Biological control, if it is to be successful for crested floating heart, will likely need to build and sustain high levels of herbivory $> 75\%$ or target other plant parts, such as stolons, roots, flowers, or seeds.

SOURCE OF MATERIALS

[1]MF-2 2lb force gauge, Shimpo Instruments, Lynbrook, NY 11563.

[2]Osmocote Plus micronutrients, ICL, St. Louis, MO 63141.

[3]Carbaryl, Sevin SL, Bayer CropScience LP, Research Triangle Park, NC 27709.

[4]Bifenthrin, UP-Star Gold Insecticide, UPL NA Inc., King of Prussia, PA 19406.

[5]JASP v0.97.1 (University of Amsterdam, Amsterdam, The Netherlands).

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