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Source: Florida Entomologist, 90(1) : 238-248

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/0015-4040(2007)90[238:IFAWTP]2.0.CO;2

INVERTEBRATE FAUNA ASSOCIATED WITH TORPEDOGRASS, *PANICUM REPENS* (CYPERALES: POACEAE), IN LAKE OKEECHOBEE, FLORIDA, AND PROSPECTS FOR BIOLOGICAL CONTROL

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ABSTRACT

Torpedograss, *Panicum repens* L., is an adventive, rhizomatous grass species that has become an invasive weed of terrestrial, wetland, and aquatic environments in tropical and subtropical regions worldwide. Until recently, strategies for controlling torpedograss in the USA have focused almost exclusively on mechanical and chemical methods, either alone or in combination, with varied results. A survey of the arthropods and nematodes currently associated with the plant in Lake Okeechobee, Florida, was conducted as part of a feasibility study to determine whether torpedograss is an appropriate target for a classical biological control program. Overall, approximately 4,000 arthropods and 400 nematode specimens were collected. Sweep, clipped vegetation, and soil core samples were dominated by representatives of the arthropod orders Hemiptera, Hymenoptera, Diptera, and Acari. Lesion nematodes of the genus *Pratylenchus* were commonly associated with the roots of torpedograss. None of the organisms collected were torpedograss specialists. Although classical biological control of torpedograss is feasible based on the extent of the infestation, economic losses, resistance to conventional controls, and the report of a potentially host specific natural enemy in India, the botanical position of this grass weed will require a formal risk assessment before proceeding with a classical biological control program.

Key Words: invasive weed, herbivory, domestic survey, weed biocontrol

RESUMEN

La conota, *Panicum repens* L., es una especie foránea de pasto que produce rizomas que ha convertido en ser una maleza invasora de ambientes terrestres, pantanosos y acuáticos en regiones tropicales y subtropicales en todo el mundo. Hasta hace un tiempo reciente, las estrategias para controlar conota en los EEUU eran enfocadas casi exclusivamente en los métodos mecánicos y químicos, solos o en combinación, con resultados variables. Un muestreo de los artrópodos y nematodos asociados corrientemente con esta planta en el Lago de Okeechobee, Florida, fue realizado como parte de un estudio de factibilidad para determinar si conota es una candidata apropiada para un programa de control biológico clásico. En general, especimenes de aproximadamente unos 4,000 artrópodos y unos 400 nematodos fueron recolectados. Muestras recolectadas pasando una red sobre vegetación mezclada, cortando la vegetación y tomando centros del suelo fueron dominados por representantes de artrópodos de los ordenes de Hemiptera, Hymenoptera, Diptera, y Acari. Nematodos en el género *Pratylenchus,* que causan lesiones sobre tejido, fueron asociados regularmente con las raíces de conota. Ninguno de los organismos recolectados eran especialistas sobre conota. Aunque el control biológico clásico de la conota es factible basado sobre la magnitud de la infestación, las perdidas económicas, la resistencia hacia los métodos de control convencionales y el informe en la India de un posible enemigo natural especifico a esta planta, la posición botánica de este pasto maleza requiere una evaluación de riesgo económico formal antes de continuar con un programa de control biológico clásico.

Panicum repens L., or torpedograss, is a rhizomatous graminaceous weed of 17 crops in 27 countries (Holm et al. 1977; Murphy et al. 1992). Torpedograss is one of the most invasive non-native, perennial grass species of terrestrial, wetland and aquatic natural areas in tropical and subtropical regions worldwide (Sutton 1996). It occurs throughout the tropics and subtropics from approximately 43° North latitude to 35° South latitude (Holm et al. 1991). The native range of torpedograss includes Europe (Tarver 1979), tropical and north Africa, the Mediterranean (Waterhouse 1994), the Arabian Peninsula, Argentina, Israel (Holm et al. 1977), and Australia (Hoyer et al. 1996).

Torpedograss was introduced into the southeastern United States as a cattle forage grass in the late 19th century (Tarver 1979). It eventually escaped cultivation and thrives in a variety of agricultural and natural settings in Alabama, California, Florida, Hawaii, Louisiana, Mississippi, and North and South Carolina (USDA, NRCS 2004), where it interferes with flood control, navigation, recreation, turf production, and irrigation (Shilling & Haller 1989; Willard et al. 1998). First reported from Mobile, Alabama, in 1876 (Beal 1896; Yarlett 1996), torpedograss apparently was not common in Florida until the 1920s (Kretchman 1962). By 1950, it was widely planted in south Florida (Hodges & Jones 1950), where it eventually formed monocultures that replaced native vegetation (Shilling & Haller 1989; Bodle & Hanlon 2001). Currently, torpedograss is listed by the Florida Exotic Pest Plant Council as a Category I invasive species because of its ability to invade and alter native plant communities (FLEPPC 2005).

With the exception of some golf courses and citrus groves that have become infested in Florida (Kretchman 1962; Fleming et al. 1978; Baird et al. 1983), torpedograss typically is a perennial weed of uncultivated riparian habitats such as ditch banks and littoral zones of Florida's canals, rivers, and lakes. Schardt & Schmitz (1991) reported that Florida spends up to $2 million annually to manage torpedograss infestations in its flood control structures. Found in over 70% of the state's public water bodies, the largest infestation of torpedograss (nearly 6,000 ha) occurs in Lake Okeechobee (Schardt 1994; Bodle & Hanlon 2001).

The absence of host specific herbivores and diseases in the introduced range of torpedograss may be one of the factors contributing to the plant's invasiveness in Florida and is consistent with the 'enemy release hypothesis' (Williams 1954; Keane & Crawley 2002). The objectives of this study were to conduct a domestic survey of the arthropods and nematodes associated with torpedograss in Florida's Lake Okeechobee watershed, and assess the suitability of this invasive grass species as a target for classical biological control. By surveying the organisms currently using torpedograss as a host plant, potentially vacant niches of the plant may be identified and perhaps eventually exploited by host specific natural enemies.

Materials and Methods

In Aug 2002, three semi-permanent transects were established along the northwest shoreline of Lake Okeechobee, Glades County, Florida, in the vicinity of the Indian River Canal, bridge C-40, 1.6 km from Highway 78, near the Indian River Campground. The survey area was dominated by torpedograss mixed with a little sand cordgrass, *Spartina bakeri* Merr., and several unidentified forbs. The specific location was geo-referenced with a handheld GPS unit; coordinates for locating the survey area were N27.064° W80.976°. The environmental conditions at the survey area (e.g., water depth and air temperature) as well as torpedograss height were recorded each time the site was visited from Sep 2002 through Jan 2003.

The 3 parallel transects were placed approximately 100 m apart. Each transect was 75 m in length and was orientated in a southwest direction from the shoreline. Sampling points were established at 5-m intervals, so that each transect produced 15 samples for each of 3 sampling methods (sweep, clip, and core). Sampling points were demarcated with engineer's flags; each flag was labeled either A, B, or C to identify the transect and numbered 1-15. Because of time and financial constraints, only 1 transect was sampled on each sample date. During the course of this short-term study, transect A was sampled twice (14-IX-2002 and 10-XI-2002), transect B was sampled twice (28-IX-2002 and 23-XI-2002), and transect C was sampled once (27-X-2002). Only one series of samples was collected along transect C because the survey site was completely flooded during the month of Dec. The sweep, clip, and core samples were collected from Sep through Dec. The rationale for using different sampling methods was to ensure that each available niche was adequately surveyed for the presence of arthropods and nematodes associated with torpedograss.

Sweep Samples

For each transect, sweep samples ($n = 15$) were collected first to capture highly mobile arthropods associated with the plant that would otherwise escape from subsequent human activity. The procedure for collecting the sweep samples was as follows: With a standard entomological sweep net the investigator walked at a normal pace, and took 20 sweeps of the net for each 5-m interval, approximately 2 to 4-m on the left side of each transect. Sweep samples were taken as close to the water surface as possible. After each sample was collected, the content of the sweep net was transferred to a labeled Minigrip® plastic bag (35.6 × 70.0 cm; 14" × 24") and placed in a ice chest; this process was repeated along the entire transect.

Sweep samples were stored in a laboratory freezer until they could be processed; usually 2-5 d after the samples were collected. The sweep samples were processed in the following manner: Plastic bags containing the sweep samples were removed from the freezer, rinsed with hot tap water, and poured into a 19.0-L (5-gal) bucket. Larger pieces of vegetation and detritus (those that would not readily fit into collection jars) were manually removed and rinsed into the bucket. The contents of the bucket were poured through 420-micron/.0165-in sieve, and the strained material was preserved in 80% denatured ethanol for microscopic examination.

Clip Samples

From 2 to 4 m on the right side of each transect, a 0.5 m^2-PVC quadrate was randomly placed within each 5-m interval and 1 large handful of torpedograss was clipped to the base of grass (the base being submerged) with a hand held clippers. A clip sample was collected for each 5-m interval, transferred to a Minigrip® plastic bag, labeled, and placed in the ice chest. To conserve space, each plastic bag was partially submerged to reduce the air and create a vacuum seal.

Clip samples were placed in a walk-in cooler in the laboratory until processed. The clipped stems, leaves, and panicles of each torpedograss sample were removed from the plastic bag, clipped in half or trimmed to fit inside a 19.0-L (5-gal) bucket, if necessary. The plastic bag was rinsed with hot tap water and the contents also poured into the bucket. This process was repeated until no visible vegetation/detritus remained in the bag. Each bucket was then filled to about one-third of its capacity with hot tap water and a small amount of liquid detergent (approximately 5-10 drops) was added as a surfactant to separate the arthropods from the vegetation. The vegetation was submerged and stirred by hand and allowed to soak while performing the same procedure on 4 additional samples. The bucket containing the first sample was then placed in a laboratory sink where the larger pieces of vegetation were removed and rinsed into the bucket. The contents of each bucket were poured through the same 420-micron sieve used for processing sweep samples and the strained material was preserved in 80% denatured ethanol for subsequent microscopic analysis.

Core Samples

To survey arthropod and nematode fauna associated with the roots of torpedograss, 2 soil core samples were collected at each 5-m interval (n = 30) along the transects on each sampling date with a Par Aide® mechanical corer; the dimensions of the cutting surface were 15 cm diam. × 10 cm height. Both soil core samples were extracted from the quadrate where the clip samples were taken. Because the soil was completely hydrated, the cores consisted primarily of torpedograss roots and rhizomes.

In the laboratory, 1 set of core samples (n = 15) was placed directly into Berlese funnels set up under 60-75-watt bulbs for approximately 2 weeks or until the soil containing torpedograss roots was completely dry. Berlese samples were processed by pouring the contents of the collecting containers through the 420-micron sieve, rinsing the sample with deionized water, and preserving the contents in 80% denatured ethanol for subsequent microscopic analysis. The second set of core samples was taken directly to the University of Florida Nematode Assay Lab, Gainesville, FL, for extraction and identification of plant parasitic nematodes attacking the roots and rhizomes of torpedograss. Only 3 sets of core samples were collected during the course of this study (14-IX, 28-X, and 10-XI-2002) because the site was completely flooded in Dec.

When possible, the invertebrates associated with torpedograss were identified to species and identifications were confirmed by specialists at the Florida State Collection of Arthropods (FSCA), Division of Plant Industry (DPI), Gainesville, Florida. Identification to genus or species for some groups not known to exhibit herbivory and considered to be transient was not attempted, although a few individuals were determined to genus or species based on the ease of identification and available keys. All alcohol and pinned specimens were deposited in the FSCA as a voucher collection labeled: 2002 Torpedograss Survey, James P. Cuda. Nematodes were discarded after extraction and identification.

The geographical origin of torpedograss and the existence of potential arthropod natural enemies were determined from the published literature. Documents containing information on what is known about the weed, including its biosystematics, distribution, economic importance (undesirable and beneficial attributes), ecological value, and potential natural enemies were examined. The scoring system of Peschken & McClay (1995) was used to determine the suitability of torpedograss as a possible target for classical biological control. The Peschken-McClay scoring system consists of 2 sections. The first section examines various economic aspects of the target weed in the following 6 categories: economic losses, infested area, expected spread, toxicity, available means of control, and beneficial aspects. The second section focuses on biological aspects of the target weed in 12 categories: infraspecific variation, geographical area where weed is native, relative abundance, success of biological control elsewhere, number of known agents, habitat stability, and number of economic, ornamental and native species in the same genus/tribe. A numerical score was selected and then assigned to each category based on the information available in the published literature. A total score was obtained by adding together the individual scores in both sections.

Results

Overall, the environmental conditions observed during the course of this study were conducive to normal growth of torpedograss. The height of the torpedograss measured from the surface of the water ranged from a maximum of 63.5 cm during the Sep and Nov surveys but eventually declined to only 6.4 cm in Jan, when the water level reached a maximum depth of 58.4 cm. The ambient temperature remained relatively constant during the first 4 site visits (26.7°C in Aug to 29.4°C in early Nov 2002) but dropped to 18.3°C in late Nov before increasing again to 21.1°C in Jan 2003.

The results of the above-and below-ground vegetation surveys are presented in Tables 1 and 2. In total, 3,826 arthropod specimens representing 12 orders, 37 families and 54 genera were collected during the course of this limited study. Of this total, 3,096 arthropods (81%) were collected in the sweep samples, 318 (8%) in the clipped vegetation samples, and 412 (11%) in the core samples. Two arthropod Classes (Insecta and Arachnida) were well-represented in this survey. Three insect Orders (Hemiptera *sensu lato* including Homoptera = Auchenorrhyncha and Sternorrhyncha, Diptera, and Hymenoptera) and 2 arachnid Orders (Araneae and Acari) dominated the sample collections.

Sweep net samples contained a higher proportion of Hemiptera and Diptera (47.5 and 29.4%, respectively) relative to the clipped vegetation (32.4 and 18.2%) and core samples (0.7 and 21.1%). Virtually all of the Auchenorrhyncha in the sweep samples were identified as leafhoppers (Family Cicadellidae) and were categorized as abundant (Table 1). Although these leafhoppers were occasionally quite numerous in the samples and capable of vectoring plant diseases, they apparently are incapable of controlling torpedograss.

Torpedograss also serves as an alternate host for several common economic pests in the Order Hemiptera. Although not as abundant as the leafhoppers, two species in the hemipteran superfamily Lygaeoidea (*Blissus insularis* Barber and *Neopamera bilobata* (Say)) were commonly collected in the sweep net samples (Table 1), and also accounted for the relatively high percentage of the hemipterans in the clipped vegetation samples. The southern chinch bug, *B. insularis*, not only attacks torpedograss and other grass species (Slater & Baranowski 1990), but is one of most economically important pests of St. Augustinegrass, (*Stenotaphrum secundatum* (Walt.) Kuntze), in Florida (Kerr 1966; Reinert 1972; Cherry & Nagata 1997). *Neopamera bilobata* (Rhyparochromidae) also is not specific to torpedograss. It attacks other non-grass plants and occasionally is considered a pest of strawberries (Brooks & Watson 1932; Slater & Baranowski 1990).

Clipped vegetation samples contained a substantial number of red imported fire ants, *Solenopsis invicta* Buren (Hymenoptera: Formicidae) (Table 1), which accounted for a greater proportion of Hymenoptera (21.1%) in these samples compared to the sweep net (4.8%) or core samples (10.0%). Red imported fire ants often bivouacked in large masses on the aerial stems of torpedograss when the site was flooded. Therefore, the success of an arthropod introduced for biological control of torpedograss may depend upon its ability to avoid predation by this invasive ant species. For example, recent studies have shown that fire ants prevented natural enemies from establishing persistent populations on the aquatic weeds waterlettuce, *Pistia stratiotes* L. and mosquito fern, *Azolla caroliniana* Willd. (Dray et al. 2001; Cuda et al. 2004).

An unidentified soil mite of the genus *Eremobelba* Berlese (Acari: Oribatida: Eremobelbidae) was the dominant arachnid collected in the core samples, accounting for 40.3% of the total specimens. Despite the large number of mites collected in the survey, they had no visible effect on torpedograss growth or survival because *Eremobelba* mites are fungivores that feed on dead or growing microflora of decaying plant tissue (Hartenstein 1962). It is noteworthy that the rhizomes of torpedograss apparently were devoid of any mining or burrowing damage from soil inhabiting arthropods. This finding is attributed to the hydrated soil conditions at the site, and suggests that perhaps an endophagous rhizome feeder could exploit this vacant niche.

Nine nematode genera were extracted from the core samples (Table 2). The most abundant nematode type associated with the roots of torpedograss belonged to the genus *Pratylenchus*. This nematode accounted for 86.5% of the total number extracted, with an average of 118.3 ± 54.2 per core sample. Nematodes of this genus are commonly referred to as lesion, root-lesion, or meadow nematodes, and are the causative agents of brown root rot in a variety of host plants (Christie 1959). All soil stages of *Pratylenchus* nematodes (juveniles and adults) infect plant roots by burrowing inside the root tissue. Whether this particular species of lesion nematode is specific to torpedograss or is capable of severely damaging the roots is unknown.

Discussion

Although a diverse arthropod and nematode fauna is associated with torpedograss in Lake Okeechobee, FL, this invertebrate complex does not appear to visibly damage the plant. Most of these organisms are generalist herbivores and are probably using torpedograss as an incidental rather than a primary host. Because this survey was conducted over a short time period (<1 year) due to limited resources, it is unknown whether there are seasonal differences in the invertebrate fauna associated with torpedograss at this site.

Torpedograss is difficult to control with physical, chemical, and mechanical control methods (Shilling & Haller 1989; Smith et al. 1993; Bodle & Hanlon 2001). In addition to being non-selective and expensive, conventional weed management practices rarely provide long-term control of torpedograss in most situations (Willard et al. 1998). In order to achieve effective long-term suppression of torpedograss in Florida and other southeastern states, all available management options should be considered including classical biological control.

TABLE 1. CONFIRMED GENUS OR SPECIES OF ARTHROPODS COLLECTED ON TORPEDOGRASS FROM 14 SEP THROUGH 23 NOV 2002, AND THEIR ABUNDANCE IN THE SWEEP NET, CLIPPED VEGETATION, AND SOIL CORE SAMPLES. SEE END OF TABLE FOR CODES AND REFERENCES.

Taxonomy	Approx. abundance	Trophic level[1]	Comments/host
PARAINSECTA			
Collembola			
Poduridae			
Podura aquatica Linnaeus	R	Scavenger?	—
INSECTA			
Odonata (adults only)			
Coenagrionidae			
Enallagma civile (Hagen)	C	Predator	—
Nehalennia pallidula Calvert	C	Predator	—
Orthoptera			
Acrididae			
Achurum carinatum (F. Walker)	C	Plant-feeder	—
Paroxya atlantica Scudder	C	Plant-feeder	—
Gryllidae			
Oecanthus quadripunctatus Beutenmüller	U	Plant-feeder	—
Tettigoniidae			
Conocephalus fasciatus (De Geer)	C	Plant-feeder	—
Orchelimum erythrocephalum Davis	C	Plant-feeder	—
Zoraptera			
Zorotypidae			
Usazoros hubbardi Caudell	C	Fungal-feeder?	—
Mantodea			
Mantidae			
Brunneria borealis Scudder	R	Predator	—
Blattodea			
Blattellidae			
Blattella asahinai Mizukubo	U	Scavenger	—
Hemiptera (includes Homoptera)			
(Heteroptera)			
Alydidae			
Alydus pilosus Herrich-Schaeffer	U	Sap-feeder	Hosts include legumes
Blissidae (Lygaeoidea)			
Blissus insularis Barber	A	Sap-feeder	Grass pest
Rhyparochromidae (Lygaeoidea)			
Neopamera bilobata (Say)	C		Strawberry pest
Pentatomidae			
Oebalus pugnax (Fabricius)	C	Sap-feeder?	Rice pest
Reduviidae			
Zelus tetracanthus Stål	R	Predator	—
Zelus sp.	R	Predator	—
Scutelleridae			
Sphyrocoris obliquus (Germar)	R	Sap-feeder	—
Thyreocoridae			
Corimelaena sp.	R	Sap-feeder	—

Codes:

Approximate Abundance: R = Rare-collected 3 times or less; U = Uncommon-collected 4-10 times; C = Common-collected regularly; and A = Abundant-numerous specimens collected on some occasions

[1]Trophic level information for herbivorous species does not imply that species included on this list were actually observed using torpedograss as a food source.

References: Chan et al. 1991; Goulet & Huber 1993; Schuh & Slater 1995; Peck & Thomas 1998; Childers & Bullock 1999; Menke et al. 1999; Peck et al. 2001; Arnett et al. 2002; RiceDoctor 2003; Cranshaw 2004; Triplehorn & Johnson 2005.

TABLE 1. (CONTINUED) CONFIRMED GENUS OR SPECIES OF ARTHROPODS COLLECTED ON TORPEDOGRASS FROM 14 SEP THROUGH 23 NOV 2002, AND THEIR ABUNDANCE IN THE SWEEP NET, CLIPPED VEGETATION, AND SOIL CORE SAMPLES. SEE END OF TABLE FOR CODES AND REFERENCES.

Taxonomy	Approx. abundance	Trophic level[1]	Comments/host
(Auchenorrhyncha)			
Cercopidae			
Prosapia bicincta (Say)	R	Sap-feeder	Ornamental, turf pest
Cicadellidae			
Chlorotettix sp.	A	Sap-feeder	Hosts include clover
Draeculacephala producta (Walker)	A	Sap-feeder	Plant disease vector?
Draeculacephala septemguttata (Walker)	A	Sap-feeder	—
Graminella sp.	A	Sap-feeder	Hosts include turfgrass, corn
Gypona sp.	A	Sap-feeder	Plant disease vector?
Delphacidae			
Delphacodes sp.	C	Sap-feeder	—
Dictyopharidae			
Rhynchomitra sp.	R	Sap-feeder	—
Derbidae			
Cedusa sp.	C	Sap-feeder	—
(Fulgoroidea)			
Flatidae			
Cyarda sp.	U	Sap-feeder	—
Issidae			
Bruchamorpha sp.	R	Sap-feeder	—
Membracidae			
Stictocephala lutea (Walker)	C	Sap-feeder	—
(Sternorrhyncha)			
Aphididae			
Hysteroneura setariae (Thomas)	U	Sap-feeder	Plant disease vector/hosts include corn
Rhopalosiphum maidis (Fitch)	U	Sap-feeder	Plant disease vector/hosts include many Gramineae
Sipha flava (Forbes)	U	Sap-feeder	Plant disease vector/hosts include sugarcane
Tetraneura nigriabdominalis (Sasaki)	U	Sap-feeder	Plant disease vector/feeds on roots of rice,soybean, onion and various grasses including *Panicum* spp.
Thysanoptera			
Phlaeothripidae			
Haplothrips sp.	C	Predator?	—
Thripidae			
Frankliniella occidentalis (Pergande)	C	Sap-feeder	Plant disease vector/greenhouse pest
Frankliniella bispinosa (Morgan)	C	Sap-feeder	Vegetable crop pest (includes citrus)
Coleoptera (adults only)			
Buprestidae			
Agrilus sp.	C	Plant-feeder	Larvae are wood-borers
Cleridae			
Isohydnocera aegra (Newman)	R	Predator?	—
Chrysomelidae			
Anisostena lecontei (Baly)	R	Plant-feeder	—
Chalepus bacchus (Newman)	R	Plant-feeder	—
Charidotella sexpunctata bicolor (Fabricius)	R	Plant-feeder	—

Codes:

Approximate Abundance: R = Rare-collected 3 times or less; U = Uncommon-collected 4-10 times; C = Common-collected regularly; and A = Abundant-numerous specimens collected on some occasions

[1]Trophic level information for herbivorous species does not imply that species included on this list were actually observed using torpedograss as a food source.

References: Chan et al. 1991; Goulet & Huber 1993; Schuh & Slater 1995; Peck & Thomas 1998; Childers & Bullock 1999; Menke et al. 1999; Peck et al. 2001; Arnett et al. 2002; RiceDoctor 2003; Cranshaw 2004; Triplehorn & Johnson 2005.

TABLE 1. (CONTINUED) CONFIRMED GENUS OR SPECIES OF ARTHROPODS COLLECTED ON TORPEDOGRASS FROM 14 SEP THROUGH 23 NOV 2002, AND THEIR ABUNDANCE IN THE SWEEP NET, CLIPPED VEGETATION, AND SOIL CORE SAMPLES. SEE END OF TABLE FOR CODES AND REFERENCES.

Taxonomy	Approx. abundance	Trophic level[1]	Comments/host
= *Metriona bicolor* (Fabricius)			
Deloyala guttata (Olivier)	R	Plant-feeder	—
Strabala rufa floridana Blake	R	Plant-feeder	—
Curculionidae			
Conotrachelus sp.	U	Plant-feeder	Genus includes deciduous tree pests
Lixus sp.	U	Plant-feeder	Genus includes crop pests and biological control species
Sibariops confusa (Boheman)	U	Plant-feeder	Hosts may include sedges
Latridiidae			
Melanophthlama picta LeConte	C	Fungal-feeder	—
Mordellidae			
Mordellistena sp.	R	Plant-feeder	Larvae are plant borers
Tenebrionidae			
Blapstinus fortis LeConte	R	Scavenger	—
Hymenoptera (adults only)			
Formicidae			
Crematogaster sp.	C	Scavenger/ predator	
Pseudomyrmex brunneus (Smith)	C	Predator	—
Solenopsis invicta Buren	A	Mainly predator	—
Diptera (adults only)			
Empididae			
Syneches simplex Walker	R	Predator	—
Stratiomyidae			
Hedriodiscus t. trivittatus (Say)	R	Nectar-feeder?	—
ARACHNIDA			
Acari			
Eremobelbidae			
Eremobelba sp.	A	Scavenger	—

Codes:
Approximate Abundance: R = Rare-collected 3 times or less; U = Uncommon-collected 4-10 times; C = Common-collected regularly; and A = Abundant-numerous specimens collected on some occasions
[1]Trophic level information for herbivorous species does not imply that species included on this list were actually observed using torpedograss as a food source.
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The suitability of torpedograss as a target for classical biological control based on the numerical scoring system of Peschken & McClay (1995) is shown in Table 3. The maximum score attainable with no known biological control agents is 179. Torpedograss received a composite score of 154. By way of comparison, the aquatic weed *Hygrophila polysperma* (Roxb.) T. Anderson, a potential target for biological control in Florida, received a total score of 153 (Cuda & Sutton 2000). Therefore, the results of this objective scoring procedure suggest that torpedograss may be a viable candidate for classical biological control based on the economic losses attributed to the weed, available means of control, the weed's native range, and habitat stability.

Because torpedograss reproduces exclusively by rhizomes (Wilcut et al. 1988) that are resistant to mechanical or herbicidal controls (Peng & Twu 1979), it may not be able to tolerate the effects of an endophagous rhizome-attacking natural enemy. For example, larvae of the moth *Metacrambus carectellus* (Zeller) (Pyralidae) were discovered feeding only on the rhizomes of johnsongrass, *Sorghum halepense* L., in Israel (Gerling & Kugler 1973). The closely related grain sorghum, *S. bicolor* (L.) Moench, was not attacked in the field by the larvae, presumably because culti-

TABLE 2. GENUS AND NUMBER OF NEMATODES EXTRACTED FROM TORPEDOGRASS ROOTS IN SOIL CORE SAMPLES COLLECTED AT LAKE OKEECHOBEE, FL, SEP-NOV 2002.

	Nematode Genus / Type								
Date	*Meloidogne* Root-knot	*Pratylenchus* Lesion	*Helicotylenchus* Spiral	*Trichodorus* Stubby Root	*Tylenchorhynchus* Stunt	*Hemicriconemoides* Sheathoid	*Paratylenchus* Pin	*Xiphirema* Dagger	*Dolichodorus* Awl
14-IX	0	172	2	0	2	0	2	0	0
28-X	20	173	2	8	0	0	0	17	1
10-XI	0	10	0	0	0	1	0	0	0
Total	20	355	4	8	2	1	2	17	1
Mean (SD)	6.7 (6.7)	118.3 (54.2)	1.3 (0.7)	2.7 (2.7)	0.7 (0.7)	0.3 (0.3)	0.7 (0.7)	5.7 (5.7)	0.3 (0.3)

vated sorghum lacks rhizomes. Moreover, an internal rhizome feeder would be able to survive the flood conditions that are conducive to the growth of torpedograss.

Nevertheless, the botanical position of torpedograss makes this grass weed a high-risk target for classical biological control (Cuda et al. 2003, 2004). Torpedograss is a member of the grass genus *Panicum*, which contains about 400 species and is the largest genus in the grass family Poaceae (Cronquist 1981). Grasses are considered the most important group of plants in terms of their impact on human society (Cronquist 1981). They not only provide food for humans and forage for domestic animals, but form extensive grassland ecosystems that support countless grazing animals and complex food webs.

Clearly, the presence of a large number of native congeners of torpedograss as well as other closely related native grasses, including threatened and endangered species and economically important graminaceous crops plants, will complicate and extend the screening process. Candidate arthropods, if they indeed exist, would require extensive host range testing to ensure that only torpedograss will be attacked. Finding natural enemies capable of demonstrating such a high level of host specificity will be a challenge. However, torpedograss is a semiaquatic species that is more likely to harbor specialized feeders compared to upland grasses (Bodle & Hanlon 2001). Moreover, the recent initiation of classical biological control programs against other invasive grass weeds in the United States, e.g., common reed, *Phragmites australis* (Cav.) Trin. ex Steudel (Blossey et al. 2002); cogongrass, *Imperata cylindrica* (L.) Beauv. (Van Loan et al. 2002); and cordgrass, *Spartina alterniflora* Loisel (Wu et al. 1999), suggests that torpedograss could be targeted for biological control.

The phytophagous mite *Steneotarsonemus* (=*Parasteneotarsonemus*) *panici* (Mohanasundaram) (Acari: Tarsonemidae) may be a promising biological control candidate (Waterhouse 1994). This mite has been recorded attacking only torpedograss in India where it causes rusting symptoms beneath the leaf sheaths (Mohanasundaram 1984), and has not been reported as a crop pest (Waterhouse 1994). According to Lindquist (1986), species of the genus *Steneotarsonemus* generally are restricted to feeding on monocotyledonous plants (grasses). Also, there is a report on a related species to suggest that torpedograss may be the only host plant for *S. panici*. Field observations by Ho & Lo (1979) indicate that *Steneotarsonemus spinki* Smiley, a congener of *S. panici*, attacks only rice, *Oryza sativa* L. They surveyed over 70 species of plants that grow in or near rice paddies in Taiwan for the presence of *S. spinki*. Of the 44 species comprising the monocot Order Graminales that were examined, includ-

TABLE 3. APPLICATION OF THE PESCHKEN AND MCCLAY (1995) SCORING SYSTEM TO ASSESS THE SUITABILITY OF TORPEDOGRASS AS A TARGET FOR BIOLOGICAL CONTROL.

Category	Rank	Score
A. Economic Criteria		
Economic Losses	Very Severe	30
Infested Area	Very Large	10
Expected Spread	Small	0
Toxicity	None or Small	0
Available Means of Control		
Environmental Damage	High	20
Economic Justification	Low or Not Justified	20
Beneficial Aspects	None or Small	0
B. Biological Criteria		
Infraspecific Variation	Small	10
Native Range	Outside USA	30
Relative Abundance	Possibly More or Not So	0
Success Elsewhere	Biocontrol Not Attempted	0
Number of Known Agents	Mite?	1
Habitat Stability	High	30
Economic Species in Genus	>1	0
Economic Species in Tribe	4-8	1
Ornamental Species in Genus	1-5	1
Ornamental Species in Tribe	1-15	1
Native Species in Genus	>20	0
Native Species in Tribe	>120	0
Total Score		154

ing 1 species in the same Tribe as rice (Oryzeae), *S. spinki* was found exclusively on rice. Based on the available evidence, the Indian tarsonemid mite *S. panici* is likely to be host specific to torpedograss and warrants further study as a potential biological control agent. By living inside the leaf sheaths of torpedo grass, *S. panici* also may be afforded some protection from fire ant predation.

Steneotarsonemus panici and other candidate arthropods would require extensive host range testing to ensure that only torpedograss will be attacked. As torpedograss is not reported as a weed of crops in tropical Africa or the Mediterranean (Holm et al. 1977, 1991; Waterhouse 1994), these regions also should be extensively surveyed for other promising natural enemies.

Although biological control is not risk free, the introduction of host specific arthropod natural enemies that are capable of damaging or killing torpedograss can provide a cost effective, long-term solution to the torpedograss problem in Florida and other states where this grass weed has become invasive. However, a formal economic and ecological risk-benefit analysis would have to be completed if a decision is made to proceed with a biological control project. Land managers charged with controlling torpedograss infestations in Florida, as well as other states where this grass has become invasive, can use the information presented here to decide whether public funds should be allocated to implement a classical biological control program against this highly invasive weed.

ACKNOWLEDGMENTS

The following individuals contributed their expertise and considerable time to the project, and their efforts are greatly appreciated. We especially thank David Almquist, Alejandro Arevalo, Kathryn Barbara, Julieta Brambila, Julie Congdon, William Crow, Judy Gillmore, Susan Halbert, Kelly Latsha, Roi Levin, Lewis Long, Greg MacDonald, Mike Sanford, Trevor Smith, Mike Thomas, and Frank Woods for contributions to this project. We thank Marc Branham and Eileen Buss for critically reviewing an earlier draft of this manuscript. We extend our gratitude to Chuck Hanlon for supporting the project (South Florida Water Management District Contract No. UPN 02082352). Use of a product brand in this paper does not constitute an endorsement by the University of Florida.

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