

Using Spatial Information Technologies to Detect and Map Waterhyacinth and Hydrilla Infestations in the Lower Rio Grande

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ABSTRACT

This paper describes a study conducted in 2002 on the application of aerial photography and videography, global positioning system, and geographic information system technologies for detecting and mapping waterhyacinth [*Eichhornia crassipes* (Mart.) Solms] and hydrilla [*Hydrilla verticillata* (L. F.) Royle] infestations in the Rio Grande in extreme southern Texas. Waterhyacinth and hydrilla could be readily distinguished in color-infrared photography, color-infrared videography, and normal color videography. The integration of the global positioning system with the video imagery permitted latitude-longitude coordinates of waterhyacinth and hydrilla infestations to be recorded on each image. The global positioning system coordinates were entered into a geographic information system to map waterhyacinth and hydrilla infestations in the Rio Grande. This survey showed an increase in distribution of these weeds of approximately 115 river-km within two counties, as compared to a 1998 survey.

Key words: aerial videography, aerial photography, *Eichhornia crassipes*, *Hydrilla verticillata*, global positioning system, geographic information system.

INTRODUCTION

South and west Texas and eastern Mexico have been in a severe drought for the past decade. Over the past 5 years, this region has received abnormally low rainfall, thus increasing the importance of irrigation and municipal diversions from the Rio Grande. The amount of water in the river available for diversions is regulated by releases from the regions two large mainstream reservoirs, Lake Amistad and Falcon Lake. The length and severity of the drought have caused significant reductions in the amount of reservoir water available. As of October 2002, Amistad and Falcon reservoirs had a combined capacity of less than 25%.

Water shortages in the Lower Rio Grande have been negatively impacted by the invasion and spread of two exotic aquatic weed species, waterhyacinth and hydrilla. Waterhyacinth is a floating species that has been called the "world's worst weed" (Cook 1990). It is a native of South America that is found in many tropical and subtropical areas of the world.

Waterhyacinth is believed to have been introduced to the United States in the 1880's in Louisiana (Tabita and Woods 1962). It is now found throughout the southeastern United States and also occurs in California (Correll and Correll 1972, Anderson 1990). Populations may double in size every 6 to 18 days and ultimately clog waterways. Several studies have reported that through the process of transpiration, the rate of water loss to the atmosphere by waterhyacinth infested areas may be many times that of areas with open water (Timmer and Weldon 1967, Rogers and Davis 1972, Mitchell 1976, Anderson and Idso 1987). However, Allen et al. (1997) argue that these large evapotranspiration (ET) to evaporation (E_0) ratios are from pot studies that do not reflect actual water use values because they expose peripheral foliage surface areas above the surrounding area, creating a "clothesline effect". They indicate that nonemergent, but exposed, floating vegetation has ET/ E_0 values of about 0.9.

Hydrilla is a submersed species that is probably native to the warm regions of Asia (Cook and Luond 1982). It is now a cosmopolitan species that occurs in Europe, Asia, Africa, Australia, South America, and North America and may be the most invasive submersed species known (Langeland 1996). Hydrilla was introduced into Florida in the 1950's as part of the aquarium trade and has since spread throughout the eastern seaboard states as well as California, Arizona, and Washington (Blackburn et al. 1969, Schmitz 1990, Langeland 1996). Once established in a system, hydrilla can alter the environment detrimentally by replacing native aquatic vegetation and affecting fish populations (Barnett and Schneider 1974, Colle and Shireman 1980, Langeland 1996). Hydrilla also interferes with movement of water for drainage and irrigation purposes and reduces boating access, thus reducing recreational uses of water bodies (Langeland 1996). By restricting flow, hydrilla can artificially raise water levels and cause increased water loss through bank absorption. Reduced flow rates in the Rio Grande can significantly affect the distribution of water for irrigation as well as for municipalities.

In 1998, Everitt et al. (1999) conducted a study using aerial videography, global positioning system (GPS), and geographic information system (GIS) technologies to detect and map waterhyacinth and hydrilla populations in the Rio Grande. The integration of these technologies provided previously unavailable information about the extent and spatial dynamics of waterhyacinth and hydrilla in the Lower Rio Grande from its mouth at Boca Chica in southeastern Cameron County to Falcon Dam in southwestern Starr County near Roma, Texas. Maps were developed denoting the distri-

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bution of infestations of these two exotic invasive weeds in the Rio Grande.

Although mechanical control methods have been employed to remove waterhyacinth and hydrilla from the Rio Grande over the past 4 years (personal communication: Earl Chilton 2002), they continue to be a major problem in the river. No new information is available on the extent and distribution of these two weeds in the Rio Grande. This paper presents results of a study conducted in the summer and early fall of 2002 using aerial remote sensing techniques, GPS, and GIS technologies to detect and map waterhyacinth and hydrilla infestations in the Rio Grande.

MATERIALS AND METHODS

This study was conducted on the Rio Grande in the Lower Rio Grande Valley (LRGV) of southern Texas. Aerial photography, airborne videography, and ground truth observations were conducted for this study.

Aerial color-infrared (CIR) photography and CIR videography were acquired simultaneously of the Rio Grande from its mouth at Boca Chica to Falcon Dam on 24 June 2002. Imagery was obtained at an altitude above ground level of 3,050 m (10,000 ft). Kodak² Aerochrome CIR (0.50 to 0.90 μm) type 2443 film was used with a Fairchild type K-37 large format (23 cm by 23 cm) mapping camera. The camera was equipped with a 305 mm lens with an aperture setting of f11 at 1/250 sec.

The CIR videography was taken with a three-camera multi-spectral digital video imaging system (Everitt et al. 1995). The system was comprised of three charge-coupled device (CCD) aligned cameras, a computer, a color encoder, and super-VHS recorder. The cameras were visible/near-infrared (NIR) (0.4 to 1.1 μm) light sensitive. Two of the cameras were equipped with visible yellow-green (0.555 to 0.665 μm) and red (0.623 to 0.635 μm) filters, respectively, while the third camera had a NIR (0.845 to 0.857 μm) filter. All the cameras had fixed lenses with 12.5 mm focal lengths.

The computer was a pentium 100 Mhz system that had an image grabbing board (640 by 480 pixel resolution) and a 1000-megabyte storage capacity hard drive. The NIR, red, and yellow-green image signals from the cameras are subjected to the RGB (red, green, and blue) inputs, respectively, of the grabbing board in the computer and also the RGB inputs respectively, of the color encoder. This permits the simultaneous acquisition of both digital and analog real-time CIR composite imagery. The digital imagery is stored in the computer hard drive, while the analog imagery is recorded on the super-VHS recorder. The hard drive can store 1000 CIR composite images.

Normal color videography (0.40 to 0.70 μm) was also acquired of the Rio Grande from Boca Chica to Falcon Dam on 19 September and 14 October 2002. The normal color video system was comprised of a Canon mini digital video camera (Model GL-1) with a zoom lens (4.2 to 84 mm) and a super-

VHS recorder. Imagery was acquired at an altitude above ground level of approximately 600 m (2,000 ft).

A Cessna Model 404 airplane, equipped with a camera port in the floor, was used to obtain the aerial photography and videography. The cameras were maintained in nadir position during image acquisition. All imagery was acquired between 0930 and 1400 hours Central Standard Time under sunny conditions.

A GPS was integrated with the video systems that acquired the latitude-longitude coordinate data of waterhyacinth and hydrilla populations on each video image. The location coordinates of each scene were entered into a computer. Before the GPS data were obtained from the scenes of waterhyacinth and hydrilla, population levels of waterhyacinth and hydrilla were assigned to each image using an ocular estimate and the following procedure: approximately 50% or greater cover of the river = dense population; less than 50% cover of the river = light to moderate population. The GPS data were entered into a GIS to generate a regional map of the LRGV that included Cameron, Hidalgo, Starr, and Willacy counties and a detailed map of a portion of Cameron and Hidalgo counties. Everitt et al. (1999) have described the GPS and GIS procedures and equipment.

Ground truth surveys were conducted at most sites where aerial photography and videography was obtained. In some instances, ground surveys were done of some sites prior to acquiring the aerial imagery. A small boat was used to conduct some of the ground surveys. Observational data recorded were plant species, cover, and water condition. Low altitude aerial reconnaissance at 150 to 300 m was also conducted at many sites to verify the presence of waterhyacinth and hydrilla.

RESULTS AND DISCUSSION

Figures 1A and 1B show aerial normal color videographic images of waterhyacinth and hydrilla infestations, respectively, in the Rio Grande near Brownsville, Texas. The imagery was acquired on 19 September 2002. The arrow on Figure 1A points to the green to dark green smooth textured image response of waterhyacinth, while the arrow on Figure 1B points to the deep dark green to nearly black tonal response of surfaced hydrilla. Trees, shrubs, and herbaceous vegetation adjacent to the river have various green tonal responses, while bare soil and sparsely vegetated areas have white, light tan and light gray tones. The GPS data are displayed at the top of the images. The latitude-longitude coordinates superimposed on the images are useful for georeferencing waterhyacinth and hydrilla infestations in the river.

Both waterhyacinth and hydrilla had similar color tonal responses to those shown in Figures 1A and 1B, respectively, in all normal color video imagery obtained of the Rio Grande. However, only surfaced hydrilla populations could be readily distinguished. Hydrilla submerged greater than 7.5 cm below the water surface generally could not be delineated from water. This agrees with the findings of the 1998 survey of the Rio Grande (Everitt et al. 1999). The turbidity of the Rio Grande in this area contributes significantly to the inability to distinguish submerged hydrilla.

Waterhyacinth and hydrilla could be distinguished in aerial CIR photography and CIR videography obtained of the

²Trade names are included for information purposes only and do not imply endorsement of or a preference for the product listed by the United States Department of Agriculture.

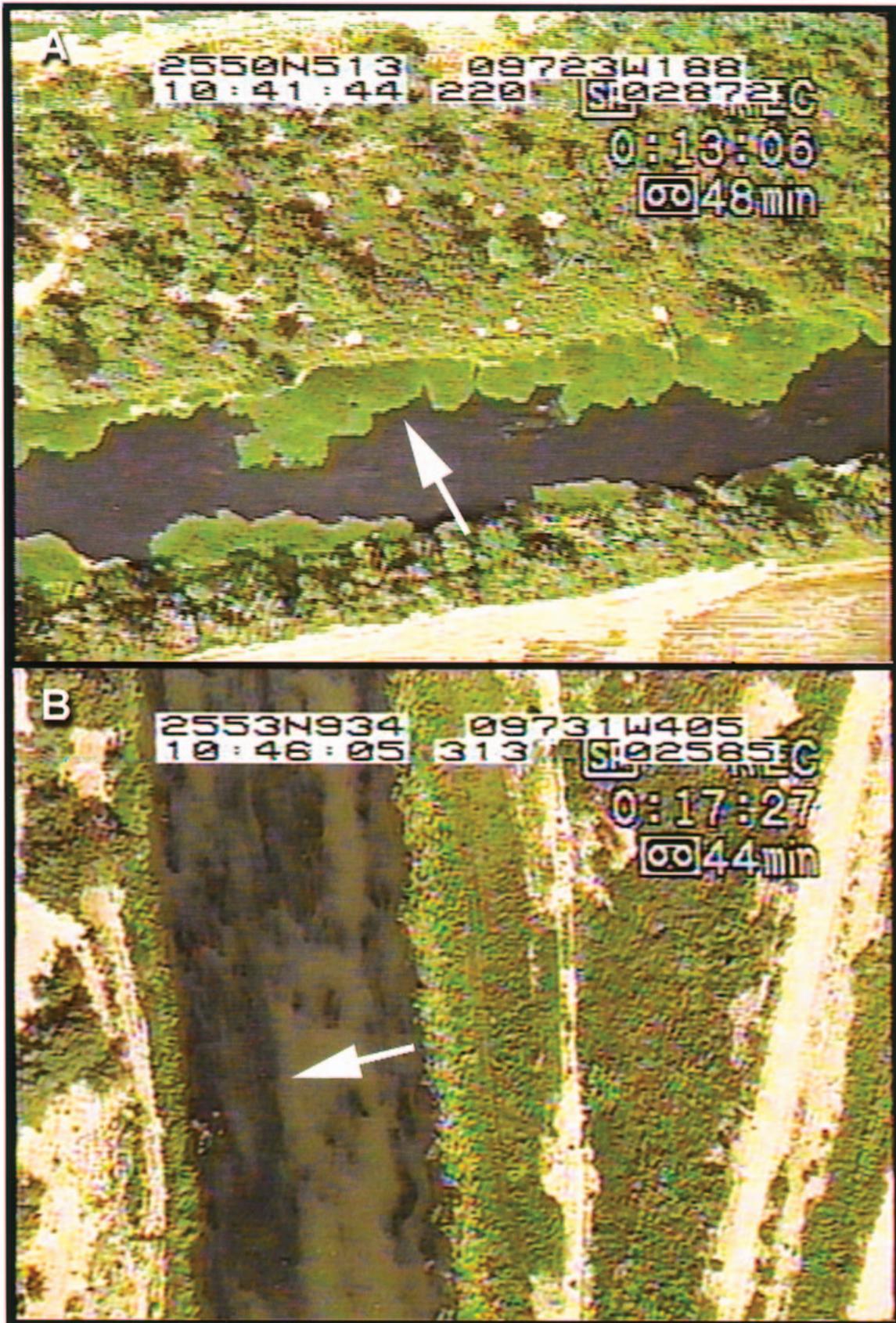


Figure 1. Aerial normal color video images of infestations of waterhyacinth (A) and hydrilla (B) in the Rio Grande near Brownsville, Texas. The arrows point to waterhyacinth and hydrilla in each respective image. The imagery was obtained on 19 September 2002 at an altitude above ground level of approximately 600 m.

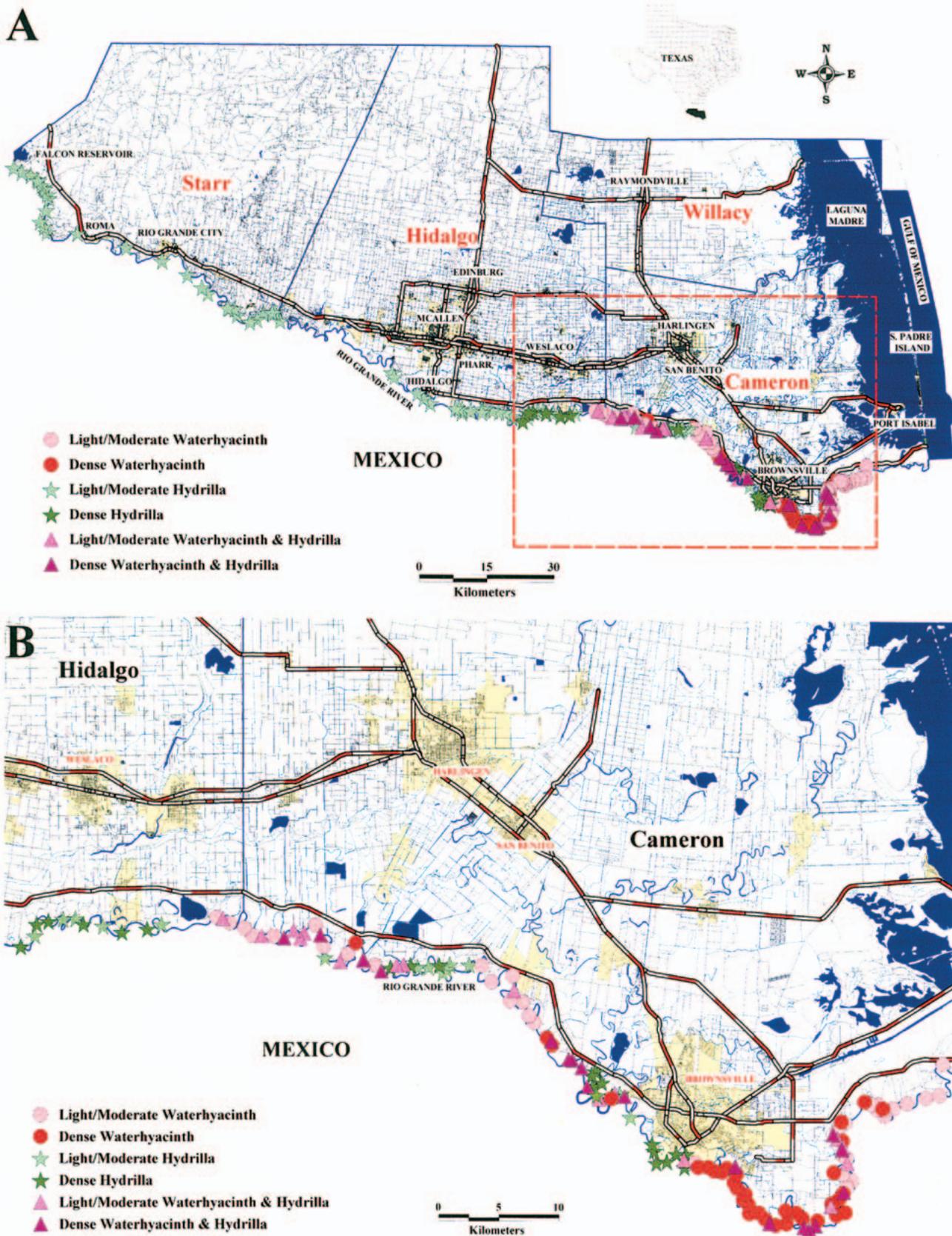


Figure 2. Regional GIS map (A) of Starr, Hidalgo, Cameron, and Willacy counties in the Lower Rio Grande Valley of south Texas. The Rio Grande forms the lower boundary of the map with Mexico. A detailed GIS map (B) of southeastern Hidalgo and Cameron counties depicting infestations of waterhyacinth and hydrilla in the Rio Grande.

Rio Grande on 24 June 2002 (imagery not shown). Waterhyacinth had a distinct red to orange-red image response while hydrilla had a reddish-brown to dark brown image. Only surfaced hydrilla could be clearly delineated in the imagery.

The CIR photography had greater spatial resolution than the CIR or normal color videography. Consequently, it provided a more detailed image of hydrilla and waterhyacinth populations and aided in the interpretation of the coarser resolution videographic imagery. However, the videography was adequate for distinguishing most of the hydrilla and waterhyacinth. Normal color videography did a better job of penetrating the water than either the CIR photography or videography. This was attributed to its sensitivity in the visible blue (0.40 to 0.50 μm) portion of the spectrum (Avery and Berlin 1992). This is in general agreement with the findings of Benton and Newnam (1976) who reported that normal color photography was useful for detection of submerged aquatic vegetation. One advantage of videography over photography is its cost-effectiveness. Airborne video surveys using analog imagery can be flown for about 25% the cost of aerial photography (Everitt et al. 1992).

Ground surveys of sites selected from the aerial photography and videography resulted in visual correct identification of waterhyacinth and hydrilla at all locations. However, a considerable amount of submerged hydrilla was found at some sites that could not be detected in the imagery. We also found small clumps of water stargrass [*Heteranthera dubia* (Jacq.) MacM.] generally less than 0.75-m in diameter intermixed with hydrilla at two sites near Brownsville and several individual plants and small patches of waterlettuce (*Pistia stratiotes* L.) which were less than 1-m in diameter intermixed with waterhyacinth at one site west of Brownsville. Neither yellow stargrass or waterlettuce could be distinguished in the imagery due to the small size of the plant populations.

The GPS latitude-longitude data obtained from the video imagery of the Rio Grande from the June, September, and October 2002 surveys were integrated with GIS technology to georeference populations of waterhyacinth and hydrilla on a regional basis. Figure 2A shows a regional GIS map of Starr, Hidalgo, Cameron, and Willacy counties of the LRGV of south Texas. The Rio Grande forms the lower boundary of the map adjacent to Mexico. The map shows the Rio Grande from its mouth in southeastern Cameron County to Falcon Dam in southwestern Starr County. Light to moderate populations of waterhyacinth have pink circles, while dense populations of waterhyacinth have red circles. The light green stars represent light to moderate populations of hydrilla, while dark green stars denote dense populations of hydrilla. For mixed populations of waterhyacinth and hydrilla, light magenta triangles represent light to moderate populations, while dark magenta triangles indicate dense populations. Due to the small scale of the map many of the symbols are stacked on each other. Most symbols represent composites of two to five video scenes. The highest populations of waterhyacinth and hydrilla occurred in southeastern Hidalgo and Cameron counties where a stretch of approximately 170 river-km were infested. Waterhyacinth was found only in Cameron and extreme southeastern Hidalgo counties. East of Brownsville 60% of most waterhyacinth infestations were dense, while 67% of most sites west of Brownsville had light

to moderate infestations. With the exception of a relatively short stretch of the Rio Grande in southwestern Hidalgo County, hydrilla occurred along most of the river from southeast of Brownsville to Falcon Dam.

Figure 2B shows an enlarged GIS map of southeastern Hidalgo and Cameron counties depicting the heaviest populations of waterhyacinth and hydrilla in the Lower Rio Grande. This area corresponds to the enclosed box in Figure 2A. This map shows greater detail of the area in regard to streets, roads, and hydrography associated with waterhyacinth and hydrilla populations.

The 2002 survey maps showed a marked increase in distribution of hydrilla in Hidalgo County as compared to the 1998 survey map of the area (Everitt et al. 1999). Hydrilla was found at only a few scattered locations in Hidalgo County in 1998 and had a distribution of about 5 river-km. Conversely, in 2002 hydrilla was found at numerous locations in Hidalgo County and had a distribution of approximately 50 river-km. Another notable change was the increase in the distribution of both waterhyacinth and hydrilla populations southeast of Brownsville in 2002. This represented an increase in distribution of approximately 70 river-km from the 1998 survey. This was probably due to the blockage of the mouth of the Rio Grande with silt and sand in 2001 and 2002 which decreased salinity levels in the lower stretch of the river and subsequently allowed waterhyacinth and hydrilla to move further down stream. Blockage of the mouth of the river was primarily due to reduced stream flow of the Rio Grande because of the long term drought. The severe infestations of weeds in the river in southeastern Hidalgo and Cameron counties probably also contributed to the reduced flow. The estimated increases in river-km of hydrilla are primarily based on surfaced beds, since few of the submerged plants could be distinguished. Therefore, our estimated total river-km of hydrilla is probably an underestimation of the actual number of river-km of this invasive species in the lower Rio Grande.

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