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# Tilapia for Biological Control of Giant Salvinia

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## ABSTRACT

In August 1999, giant salvinia (*Salvinia molesta* Mitchell) was found along the lower Colorado River in irrigation drainages. To investigate the slow spread and apparent control of giant salvinia in this region, the herbivorous fish, tilapia (*Oreochromis niloticus* Trewavas), was examined as a biological control agent. The study was conducted in a 5,000-L recirculating system. One of four treatments was assigned to each of twenty 200-L tanks after they were stocked with tilapia at a density of five fish per tank. The first treatment group, the giant salvinia control, contained giant salvinia only; group two, the fish control, contained fish only and was fed a commercial diet; group three, the giant salvinia and fish minus feed treatment, contained fish and giant salvinia; and group four, the giant salvinia and fish plus feed treatment, contained fish and giant salvinia, as well as being fed a commercial diet. Changes in giant salvinia biomass were statistically different among all treatments ($p < 0.0001$, $F_{2,12} = 49.4370$), with greatest change occurring in the giant salvinia and fish minus feed treatment (-491 g). Average fish growth was 13.7 g greater in the giant salvinia and fish plus feed treatment than either the fish control treatment or the salvinia and fish minus feed treatments. These findings could explain why giant salvinia has had limited dispersal on the Lower Colorado River, as tilapia are ubiquitous.

*Key words*: aquatic plants, Lower Colorado River, nuisance species, *Oreochromis niloticus*, *Salvinia molesta*.

## INTRODUCTION

Known as Kariba weed, African pyle, aquarium water moss or koi kandy, giant salvinia is native to southern Brazil, but has been widely distributed to many parts of the world (Mitchell 1979). Under favorable conditions, this floating water fern can become a devastating aquatic nuisance, disrupting native species as well as human activities by rapidly covering large areas. Capable of explosive growth, giant salvinia can block waterways, hindering both fishing and other recreational activities (Mitchell et al. 1980). The first record of giant salvinia being transported out of its native range was in 1939, when it was introduced by the botany department at the University of Columbo in Sri Lanka (Williams 1956). It has since been moved to Australia, Papua New Guinea, southern India, Namibia, Botswana and South Africa (Room 1986, 1990). Experimentation and research into classical biological control of this rapidly growing weed with host specific arthropods has brought its population under control in each of these countries (Julien and Griffiths 1998).

Giant salvinia is a free-floating, clonal fern that can only reproduce vegetatively. Outside of its natural habitat, the plant is eaten by few herbivores, allowing it to grow unfettered in warm, slow moving waters. In most cases the range of this plant is temperature limited; giant salvinia survives extremes of -3 C and 43 C (Whiteman and Room 1991), but optimal growth occurs at 24 C to 28 C (Cary and Weerts 1983). Stands of giant salvinia can double in 2.2 days when supplied with adequate nutrients (Cary and Weerts 1983). During periods of high growth, leaf size decreases and both leaves and stems fold, doubling and layering to cover more of the water surface (Room and Julien 1994). This thick growth has proven to be harmful to other species, as it blocks light to plants growing below, reduces gas exchange and increases biological oxygen demand as old growth falls to the bottom and decomposes (Thomas and Room 1986).

Attempts at biological control of giant salvinia have focused on three species: an aquatic grasshopper (*Paulina acuminate* de Geer) (Sands and Kassulka 1986); a moth (*Samea multipliculis* Guenee) and a weevil (*Cyrtobagous salvineae* Calder and Sands) (Room et al. 1989), all are natural grazers from giant salvinia's native range. Various experiments with giant salvinia and its natural predators have been conducted. Biological control studies focusing on the weevil, moth or grasshopper have largely examined temperature ranges of the predatory herbivores and their host specificity. Results largely show similar rates of giant salvinia destruction among the three herbivores (Forno and Bourne 1986), however, a few studies have shown the weevil to be more effective than the moth at controlling giant salvinia (Room et al. 1984). As a consequence, much effort has gone into utilizing the weevil as the primary biological control of giant salvinia. Controlling giant salvinia with herbicides has also been explored (R. Helton, Texas Parks and Wildlife Department, personal communication). To date, minimal research has explored using fish as a biological control of giant salvinia.

In 1999, giant salvinia was discovered along the banks of the Colorado River, growing in small mats beneath overhanging vegetation (S. Stefferud, U.S. Fish and Wildlife Service, pers. comm.). The source of the infestation has been identified as the main drainage canal of the Palo Verde Irrigation District (PVID) in California, which discharges free floating fragments of giant salvinia to the river proper. Giant salvinia has since been carried downstream to reservoirs and supply canals. Now that giant salvinia has spread to these areas, management of municipal and agricultural water supply canals will likely be impacted by higher weed control costs. Currently, managers of these canals use a variety of weed control methods, including chemical and mechanical treatments. Triploid grass carp (*Ctenopharyngodon idella* Valenci-

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ennes) and tilapia have previously been introduced in some of the canals infested with giant salvinia along the lower Colorado River and may contribute to the biological control of this invasive weed (Costa-Pierce and Doyle 1997).

The current study was designed to explore the use of herbivorous fish for biological control of giant salvinia. As mentioned previously, triploid grass carp and tilapia could play an important role in controlling giant salvinia. However, the role of fish in controlling giant salvinia has not been investigated. This study was designed with two specific objectives in mind: to quantify the impact that tilapia will have on a standing crop of giant salvinia and to determine if tilapia benefit nutritionally from consuming giant salvinia as measured by weight gain.

## MATERIALS AND METHODS

A two-part experiment was conducted over 23 days at the University of Arizona's Environmental Research Laboratory to evaluate the use of tilapia for biological control of giant salvinia. Captive populations of tilapia were housed in a greenhouse containing a semi-closed recirculating system. Fish were fed a commercial tilapia feed from Integral Fish Feeds in Grand Junction, CO two times each day at 08:00 and 14:30 at an average of 2% body weight per day. The majority of the water was recirculated through a series of mechanical and biological filters and returned to the system with less than 1% water exchange per day. Wastewater was discharged directly into the municipal sewer system.

The experimental culture system, which contained a total of 5,000 L, consisted of 20 tanks, each with a volume of 200 L plus a 1,000-L sump was prepared to test giant salvinia consumption by tilapia and subsequent tilapia growth. This system was housed in the same greenhouse as the main tilapia holding system and was situated under a 70% light transmission shade-cloth to mimic growing conditions along banks of the Colorado River. A recirculating system was chosen to minimize temperature and water quality differences among experimental groups during the study period. The 20 tanks were initially filled with a combination of municipal water and water from the main tilapia holding system. No water was discharged from the experimental system while the feeding trial was in process, in order to ensure containment of giant salvinia. Municipal water was added to compensate for evaporation. Water quality parameters including dissolved oxygen, pH and temperature were monitored weekly to ensure suitable conditions for viable growth.

Three-month-old fish were randomly selected from the captive population of tilapia. Thirty fish were tagged using five tag colors, enabling easy identification of individual fish for monitoring growth. Tagged tilapia with an average weight of 88 ± 35 g were stocked at a density of five fish per tank into the 5,000-L experimental system. Fish were acclimated in the test system for 2 weeks prior to the giant salvinia feeding trial, during which time all tanks were supplied with a commercial tilapia diet two times per day at 2% of the initial body weight per day.

Each of the 20 tanks was then randomly assigned to one of four treatment groups. In order to assess the growth rate of the giant salvinia in the experimental system and determine a baseline of fish growth in the experimental system, the first and second treatment groups served as controls. Tanks in the first treatment group, the giant salvinia control, contained only giant salvinia, as fish were removed from these tanks after they were assigned to a treatment group, while tanks in the second treatment group, the fish control, contained fish only. Tanks assigned to the third group, the giant salvinia and fish minus feed treatment, and fourth group, the giant salvinia and fish plus feed treatment contained both giant salvinia and fish. Fish in the fish control and giant salvinia and fish plus feed groups were fed a commercial tilapia diet.

Giant salvinia was added to tanks in the giant salvinia control treatment, the giant salvinia and fish minus feed treatment and the giant salvinia and fish plus feed treatment at a rate of 380 grams wet weight per tank, enough to cover approximately 75% of the water surface. In order to obtain more accurate measurements, excess water was gently squeezed from the giant salvinia while it was being held in a dip net prior to weighing. Giant salvinia was monitored daily by visual inspection in these tanks to assess standing biomass. Tanks in which all plant matter was consumed, were given additional giant salvinia up to the predetermined tank limit of 1 kg by the addition of one 380-g portion followed by one 240-g portion, as needed.

On day 14, all fish and the standing giant salvinia biomass were weighed and returned to their respective tanks. At this time, tanks assigned to the giant salvinia control were harvested. When fish in the first tank consumed their 1-kg allotment of giant salvinia on day 23, the experiment was terminated. On day 23, as on day 14, all fish and any remaining giant salvinia were weighed. For both day 14 and day 23, fish were weighed individually and weights were recorded by tank number and tag color to monitor growth of individual fish. Giant salvinia was drained of excess water prior to weighing, as described above.

Following completion of the experiment, data were analyzed using the statistical software package JMP IN 4 (SAS Institute Inc., USA). In both cases, a one-way ANOVA followed by a Linear Contrast was used to separate the means. The significance level was set at $\alpha = 0.05$.

## RESULTS AND DISCUSSION

Environmental conditions in the experimental system over the 23 days of this study were well within the acceptable limits for both tilapia and giant salvinia. Temperature ranged from 23.4 C to 25.4 C. Dissolved oxygen ranged from 7.43 mg/L to 7.76 mg/L.

### Quantification of the impact of tilapia on the standing crop of giant salvinia

After 14 days, the standing biomass of giant salvinia in both the giant salvinia and fish minus feed and the giant salvinia and fish plus feed treatments was less than the biomass in the giant salvinia control (Table 1). On average, 491 g of giant salvinia was consumed per tank in the giant salvinia and fish minus feed treatment ($p < 0.0001$, $t = 9.8901$, df = 12). Similarly, standing biomass of giant salvinia was reduced by 301 g per tank in the giant salvinia and fish plus

TABLE 1. CHANGES IN MEAN GIANT SALVINIA BIOMASS OVER 14 DAYS IN TANKS THAT CONTAINED NO FISH, TANKS CONTAINING FISH WITH GIANT SALVINIA AS THE SOLE FOOD SOURCE OR TANKS WITH FISH OFFERED A COMMERCIAL DIET IN ADDITION TO GIANT SALVINIA.

| | Biomass (g) of Giant Salvinia (mean ± standard error) | | | |
|---|---|---|---|---|
| Treatment | Initial | Added | Day 14 | Change[1] |
| Giant Salvinia Control | 380 ± 0.0 | 0.0 ± 0.0 | 353 ± 15.2 | -27 ± 34.0* |
| Giant Salvinia and Fish Minus Feed | 380 ± 0.0 | 228 ± 208.1 | 117 ± 54.2 | -491 ± 117.4* |
| Giant Salvinia and Fish Plus Feed | 380 ± 0.0 | 0.0 ± 0.0 | 79 ± 17.6 | -301 ± 39.4* |

[1]Means followed by an * are statistically different at $\alpha = 0.05$.

feed treatment, 274 g more per tank than tanks in the giant salvinia control treatment ($p < 0.0001$, $t = 5.8365$, df = 12). Tanks in the giant salvinia and fish minus feed treatment group consumed 190 g more giant salvinia, on average, than tanks in the giant salvinia and fish plus feed treatment ($p = 0.0016$, $t = 4.054$, df = 12).

## Tilapia growth as a result of eating giant salvinia

Fish growth in tanks assigned to the giant salvinia and fish minus feed treatment group was lowest (Table 2), with a mean weight loss of 11.9 g per fish, whereas fish in the fish control treatment increased their weight by an average of 6.4 g per fish, a difference of 18.3 g per fish ($p < 0.001$, $t = 4.7574$, df = 67). Fish in the giant salvinia and fish plus feed treatment grew 13.7 g per fish, 7.3 g more than the fish in the fish control treatment ($p = 0.0753$, $t = 1.8068$, df = 67). The difference in growth between fish in the giant salvinia and fish minus feed treatment and the giant salvinia and fish plus feed treatment was 25.6 g ($p < 0.001$, $t = 6.4169$, df = 67).

## Implications

Effective control of aquatic nuisance species is critically important, as the cost of such invasions continues to rise, both financially and environmentally. Observations of giant salvinia in other ecosystems around the world have demonstrated the potential for severe impacts on the lower Colorado River through rapid propagation leading to complete coverage of reservoirs, irrigation supply canals and municipal water intakes resulting in increased weed control costs. In addition to the potential financial burdens brought about by the spread of giant salvinia, environmental impacts could be extensive. Environmental problems are not limited to the obvious clogging of waterways and competition with native species. Herbicide use and mechanical control would have an additional impact on the river's natural flora and fauna. However, in over 2 years since its discovery in the Colorado River, giant salvinia has not appeared to form large infestations in the backwaters or along the riverbanks and propagule transport has not increased appreciably (Jennifer Green, Bureau of Land Management, personal communication). A variety of factors may be interacting on the river proper to limit growth downstream.

In many ways the PVID outfall drain has acted as a nursery for giant salvinia growth. Water temperatures in the drain are higher than the river proper, as the drain is not as deep and collects both leachate and excess irrigation water from field application. Cary and Weerts (1983) showed that giant salvinia growth increases more quickly at 24 C, compared to lower temperatures. Therefore, while temperatures in the river never reach lethally low levels of -3 C (Whiteman and Room 1991), temperature ranges are below those optimal for growth. Water current is faster in the river than the canal and wave action is increased due to heavy boat traffic to the south of PVID. Torien et al. (1983) identified increased wave action as a factor detrimental to growth of giant salvinia. Along with these impacts on giant salvinia, this study identifies another potential source of giant salvinia control in the Colorado River.

Differences in giant salvinia consumption among the three treatment groups suggest that control may be achieved by the presence of tilapia. Alternatively, the observed weight loss exhibited by the tilapia offered giant salvinia as the sole source of food, could suggest that tilapia are not likely to consume giant salvinia in the wild. Additionally, tilapia were not exposed to the variety of feeding options found in the river, and are therefore less likely to be major consumers of giant salvinia when presented with other feed choices. However, despite the clear lack of nutritional benefit that giant salvinia provides to tilapia, tilapia do impact the standing biomass of giant salvinia, even when offered a nutritional alternative, as evidenced by the reduction of giant salvinia in the giant salvinia and fish plus feed treatment tanks.

TABLE 2. CHANGES IN MEAN FISH WEIGHT OVER 23 DAYS WHEN OFFERED A COMMERCIAL FISH FEED ALONE, GIANT SALVINIA ALONE OR THE TWO IN COMBINATION.

| | Fish Weight (g) (mean ± standard error) | | |
|---|---|---|---|
| Treatment | Day 0 | Day 23 | Change[1] |
| Fish Control | 91.1 ± 5.9 | 96.6 ± 6.2 | 6.4 ± 8.9* |
| Giant Salvinia and Fish Minus Feed | 89.2 ± 7.3 | 77.3 ± 6.3 | -11.9 ± 6.7* |
| Giant Salvinia and Fish Plus Feed | 84.8 ± 7.6 | 104.8 ± 10.7 | 13.7 ± 21.4* |

[1]Means followed by an * are statistically different at $\alpha = 0.05$.

Currently, major populations of giant salvinia have essentially been contained in the irrigation drainages in which it was first identified along the Colorado River. To date, the exact reason for the containment is not known. While it is unlikely that tilapia have a major influence on the standing biomass of giant salvinia, when coupled with the aforementioned environmental impacts on giant salvinia in the river, it would appear that even partial biological control may play a significant role. Containment, therefore, may well be influenced by the presence of tilapia in this area.

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