# Waterscaping Water Chestnuts: A Test of Improving Habitat for Fish

A Final Report of the Tibor T. Polgar Fellowship Program

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Frenzel, J. and K. Limburg. 2004. Waterscaping water chestnuts: A test of improving habitat for fish. Section IV: 31 pp. *In* W.C. Nieder & J.R. Waldman (eds.), Final Reports of the Tibor T. Polgar Fellowship Program, 2003. Hudson River Foundation.

**Abstract**

Invasive species are increasingly common in the waterways of the United States. Eurasian water chestnut (*Trapa natans*) was introduced in Concord, Massachusetts in 1859. Since then it has spread throughout much of the East Coast and continues to expand westward. Because of its prolific seed bank and dense growth it is causing unsuitable conditions for submersed aquatic vegetation and fish communities alike. It has increased to the point were it may be impossible to eradicate, but we may be able to find a way to allow our native species to live along side it.

A large chestnut bed in Tivoli South Bay (Tivoli, NY) was manipulated by clearing two paths into it. In doing so we formed a smaller site (comprised of the edge of the large bed) between the clearing and an open channel in the bay. These three sites were compared to our controlled site located near Cruger Island. Our areas of interest were the dissolved oxygen concentrations and the fish communities found within each site. Dissolved oxygen concentrations were monitored with hand-held and submersible YSI multiprobes throughout the duration of the study. Fish were collected with pop nets, rotating the pop nets from site to site throughout the study.

We found that average dissolved oxygen concentrations were lower in the large bed than the other three sites. However, the most species and the highest total of fish caught were found in the large *Trapa* bed. The highest biomass was found in the edge site, which yielded the second highest amount of total fish caught. The clearing proved to hold up an increased dissolved oxygen level but yielded the fewest total fish caught and the lowest biomass.

Overall the large *Trapa* bed was still frequented by the fish community found in the bay. It is being used as protection, from aerial and aquatic predators, for the year of young and the smaller fish species. However, when the ebb tide conditions are reached the dissolved oxygen levels are to low to sustain the fish communities forcing the fish into the edges and the open water until the conditions are once again suitable.

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## Introduction

*Trapa natans* (Eurasian water chestnut) is an invasive species that since the late 1800's has been gradually taking over back waters of the Hudson River Estuary and other aquatic systems in the northeast. *Trapa natans* grows rapidly when in season and can survive in waters from two centimeters to two meters deep.

Water chestnut is an annual, which in summer grows rapidly and can reach a length of 16-feet long. It produces two sets of leaves, one being submergent and the other emergent. The emergent leaves are triangularly shaped and toothed. These leaves grow as rosettes, producing about 20 seeds per rosette. One reason for water chestnut's success is the prolific seed bank that has built up in the sediment. The seeds may survive up to 12 years in sediment, and over time many sprout successfully.

*Trapa* grows densely and this has caused the displacement of some native aquatic species. The primary species that it appears to have replaced is *Vallisneria americana*, resulting in a fundamentally different plant community. *Vallisneria amaricana* contains subsurface-oxygen-producing structures. However, *Trapa natans* primarily produces oxygen on the surface, therefore it is producing little oxygen within the water column (Coote et al. 2001). Low oxygen levels prevent many fish from using the habitat, and this issue was part of the motivation for this study.

Because *Trapa natans* releases oxygen into the atmosphere and not the water column, dissolved oxygen levels tend to drop. During ebb tide conditions, dissolved oxygen levels can be depleted to hypoxic and even anoxic conditions (Caraco and Cole 2002). During ebb tide conditions, numerous small fish exited the water chestnut beds (Coote et al. 2001). This suggests that (1) water chestnut may provide refuge from predators, but (2) when oxygen declines on ebb tides, small fish are forced to leave the refuge.

In the Hudson River, water chestnut beds serve as spawning sites for *Cyprinus carpio* (carp) and also provide protection to smaller fish species such as *Etheostoma olmstedi* (tessellated darters) and *Fundulus diaphanus* (banded killifish). These vegetated areas also provide small species protection both from aerial predators and from aquatic predators such as bass and white perch. The vegetation also protects young-of-year (YOY) of larger fish until they are mature enough to enter the more open areas such as the channel and the river. Carp (*Cyprinus carpio*) larvae emigrate from South Tivoli Bay to the estuary. The bay is protecting the carp larvae until they are mature enough to be exported from the bay to the estuary (Bohne and Schmidt 1989).

The purpose of this study was to manipulate a large *Trapa* bed so that the habitat for fish would be suitable for them to remain during ebb tide conditions. Water chestnut is not easily eradicated, but perhaps may be managed to improve it as habitat for fishes. We tested one such measure, called "waterscaping" (Summerfelt 1999), in which pathways are cut into water chestnut beds. These paths would serve two purposes. The first is that they would form a smaller chestnut bed that could be monitored and compared to the larger chestnut bed. The second would be that the paths would permit more oxygenated water from outside the bed into the clearing and to the surrounding areas of the existing *Trapa*. For more comparison, a smaller *Trapa* bed at another site would also be monitored. The results found at this site would be compared to the larger bed, the smaller constructed bed, and to the cleared paths. We would be monitoring fish and water quality in and around the large *Trapa* bed, the smaller *Trapa* bed, the clearing, and the reference site. We hypothesized that the habitat found in the smaller bed and areas surrounding the clearing should begin to resemble the habitat found at the reference site.

## Materials and Methods

The waterscaping manipulation was set up in Tivoli South Bay because of the high abundance of water chestnuts found in the bay. Tivoli South Bay is approximately 115ha. Of this, *Trapa natans* covers about 95% of the surface from mid-May through October (Anderson and Schmidt 1989). Tivoli South Bay is separated from the mainstream of the Hudson River by the railroad, but three railroad bridges allow tidal exchange from the bay to the river. The study site is located just south of the middle bridge, near the center edge of the bay.

The first hurdle to overcome was to remove the water chestnut. I had originally planned to have two people pull a weighted rope along the substrate, and in doing so the chestnut might be ripped at the base of the stems, but the manpower necessary was unavailable. Therefore, it was done by hand. All that was needed was a canoe and waders. When I would pull it up I would allow the water to drain and then place it into the canoe. When I would fill the canoe it would then be pulled to the shore and off loaded on the banks. I was careful to place the weeded plants at least a meter above the high tide mark seen on the rocks so that they would not be redistributed into the bay at high tide.

Following the creation of the clearing, *Trapa* on the edges needed to be held back so that it did not float back together. Two-meter tall garden posts were placed every 5m along the edge of the clearing. They were topped off with wooden dowels that were 1m in length and 7mm wide. These posts were then marked with red duct tape. The reasoning for the extension of the gardening posts was so that the site could be easily spotted if the waters were to exceed the heights of the gardening posts during flood tide.

After the posts were in place 7-mm deer fencing was then strung along the length of the clearing. The deer fencing came 33 m long and was 2 m wide. This was more than adequate to line two sides of the clearing. The fencing was cut into two symmetrical pieces going the length of the fencing. The fencing was then tied by the top, center, and bottom onto the gardening posts. The bottom of the fencing was under water during ebb tide so it caught the chestnut when the vegetation was lower. There was a gap ranging from 15-45 cm between the sediment and the bottom of the netting in order to allow fish to enter and leave the clearing freely. When the construction of the site was completed there were two cleared paths. The first, which ran perpendicular to the railroad tracks, was 32 m long with an average width of 5m. The second clearing ran parallel to the tracks and formed a "T" with the perpendicular clearing. This parallel clearing was 26.5 m long with an average width of 6 m.

When clearing was completed and the fencing set up there were three areas to sample. The first was the original large bed that still covered the rest of the bay south of the clearing, the second was the clearing its self and the third, was the small *Trapa* bed formed between the open channel from where the water flowed in and out during the changing tides.

Figure 1: Photograph showing the clearing, small edge bed, and large *Trapa* bed.

The smaller bed that was formed was on the edge of the open water. It was 32 m long and varied between 20 and 25 m wide. These three sampling sites were compared to a small reference bed located near Cruger Island.

Cruger Island was picked to be the comparison site because of its smaller *Trapa* bed and the relative proximity and ease of sampling. Because the bed was smaller it was presumed that the dissolved oxygen levels would not reach the anoxic levels that were to be found in the large bed during ebb tide conditions. Cruger Island is found off of the northern end of South Bay and is located on the riverside of the railroad tracks.

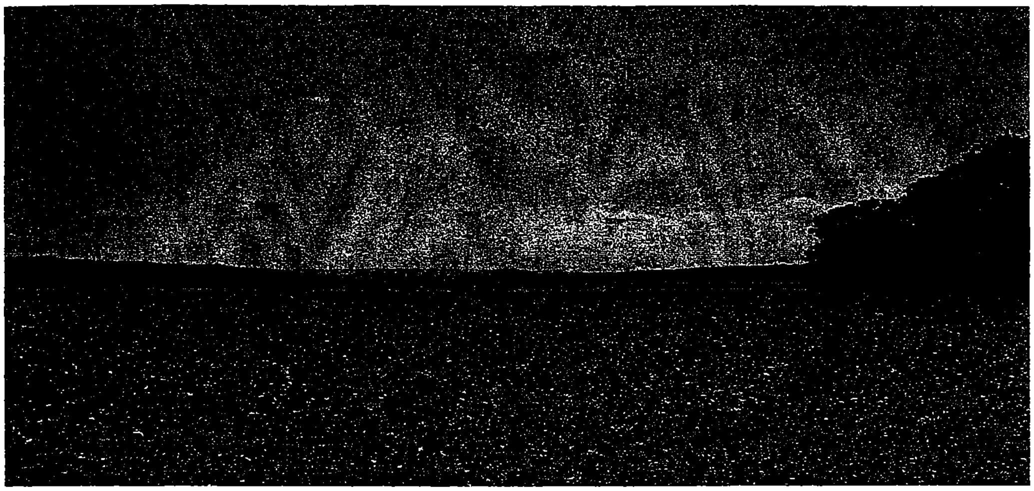

Figure 2: Photograph from center of Cruger Island site.

It is a smaller bay that is roughly 75 m wide by 120 m long. It is formed between Cruger Island and the railroad tracks, and although is more prone to the activities of the river due to its location, was determined to be a valuable comparison site of the three sites created in Tivoli South Bay.

**Fish Collection**

For the project, two pop nets were built using the design described by Schmidt et al (2002). Pop nets have proven to be an effective means for sampling fishes from dense aquatic vegetation (Pelczarski and Schmidt 1991). The mesh size used for the nets was 3/16 inch and was sewn together to fit the trap parameters with 8 lb. test fishing line. On the first trap I filled the weighted half of the trap with cobble rather than the suggested 20-foot lengths of

3/16 inch rebar. The weight proved to be insufficient and, therefore, this trap needed four 25 lb. free weights placed on the corners of the trap (one per corner). The second trap was built with rebar but with 24 feet instead of 20 feet to ensure that there was adequate weight to hold the bottom of the trap down on the substrate.

The traps were set near or at ebb tide conditions and were popped two to three hours after the flood tide. Each location had a total of five pop net samples, spread out during the course of July and August (Table 3). When popping the nets it is necessary to involve at least two people. The same is true for seining the popped trap. If three people are available, two can seine the trap while a third removes the fish from the seine when it is pulled out of the trap. The seining was not completed or the trap considered empty until there was five consecutive pulls that yielded no fish.

**Fish Assessment**

When fish were collected from the seine they were placed in mason jars that were filled with 75% alcohol as a preservative. The mason jars were also labeled by the site and date that the trap was popped. The fish were later identified, abundances recorded, weighed on an electronic scale to the nearest tenth of a gram, and their total lengths (nose to end of caudal fin) recorded by millimeters. With the data from each fish and from each site and date, biomass was calculated for each species of fish for each popping at each site. These biomasses were recorded to $g/m^2$ and were compared. The total biomasses for each site (five biomasses at each site combined) were also calculated as well as an average biomass for each pull/site.

Shannon-Weiner diversity indexes were computed with the total abundances of fish and species to see if there were any differences in fish communities found at the different sample sites.

The formula used for the diversity index was:

$$H' = -\,\text{sum}\,(\,Pi * \ln(Pi))$$

Here H' is the diversity index and Pi is the fraction of the sample represented by the $i^{th}$ species.

**Water Chemistry**

Water quality in the four sites was assessed with HOBO light intensity data loggers, YSI sondes, and a YSI hand held multiprobe. The light intensity loggers and the YSI sondes could be deployed continuously over several days to weeks, and the multiprobe was used to make calculated samples over a larger spatial area.

The HOBO light intensity data loggers measured the relative intensity of light in the water column. Two were used in the study and were strategically placed in the clearing and the large *Trapa* bed. The first deployment was begun on July $15^{th}$. The first light meter was placed in the south end of the perpendicular clearing and was tied to a cinder block and then to a gardening post. When let free the meter floated 15 cm above the substrate. The meter was set to take readings every fifteen minutes for two weeks. The second meter was placed 5 m into the large *Trapa* bed and was tied down and floated in a manner similar to the meter in the clearing.

After the two-week period the light meters were retrieved and the data were downloaded. The meters were then set to the same parameters as the first setting and were returned to the field. There was a slight change in the placement of the meter in the *Trapa*, where instead of leaving it at 5 m into the bed, the light meter was set roughly ten meters into the bed.

On July 28, 2003 (same day as light meters were retrieved and reset), the first of the submersible YSI sondes were set. The first one was set with the HOBO light meter in the clearing and the second was set 50-60 m into the large *Trapa* bed. Both of the sondes, borrowed from the Hudson River Research Reserve, were placed in protective cages that were weighed down with four bricks each. For further precaution the sondes were also tied to gardening posts to prevent them from being lost in the case of high tide or storms.

The purpose of the submersible sondes was to retrieve continuous data on the dissolved oxygen levels (DO) as percent of saturation and mg/L. The sondes also recorded the fluctuation in temperature (C), pH, and depths so that all the data could be matched with the tides. Two other meters were set at later dates: one in the small Trapa bed and one at Cruger Island. These sondes were set August 6, 2003. Again they were tied to posts and waited down to prevent the loss of the tools. They were also recording the same properties as the two set the week earlier.

The YSI-hand held multiprobe was also equipped to measure DO, temperature, and pH, but can not be used to gather continuous data. Instead it was used on two separate occasions (July 15 and 28, 2003) to obtain water quality data.

In the large *Trapa* bed we started at the south end of the parallel clearing and recorded the DO, temperature, and pH. The probe was held 40cm under the surface of the water and the data recorded as we moved along every 5 m for 50 to 65 m (50 m on the 15th and 65 m on the 28$^{th}$) southward in the bay.

In the clearing we recorded the variables at its center, on the north and south ends of the parallel clearing, in the middle of the parallel clearing, and at the end (near train tracks) of the perpendicular clearing. Again the testing was done 40 cm below the surface.

The smaller clearing was sampled with the multiprobe, starting at the southwest corner of the bed and then running through it diagonally, recording every 5 m. We then made a measurement at the edge of the bed, in the open channel, and in the current of the channel so that these could be compared with the other readings. To stay consistent with the previously tested sites the readings were done 40 cm below the surface.

The last site sampled with the multiprobe was Cruger Island. The sampling here was started in the middle of the *Trapa* bed and then headed towards the edge that opened to the river. The recordings were made every 5 m again at a depth of 40 cm. The edge of the bed (were the bed meets open water) was recorded and then one in the open river for a greater range of comparable data that may show the adverse affects that they *Trapa* may potentially be having on the water quality.

All the sampling in these sites with the YSI multiprobe was done from a canoe so that the substrate was not stirred up. This may have caused some variance or imperfections in the data if done otherwise. We came to this conclusion when two of the readings were done in the clearing while standing in the water and some of the data looked a little affected by the disturbances that we had caused in the substrate.

## Results

Water chemistry was tested throughout the duration of the study through different means. Figure 3 shows the distributions of the oxygen levels over a large *Trapa* bed and for the clearing. Dissolved Oxygen was relatively stable while traversing the large bed; however around 50 m into the site, the DO levels dropped off quickly (Figure 3b). When comparing this to the other DO samples gathered in the clearing and the large bed Figures 3a, c, and d, the DO levels are all relatively in the same vicinity until testing that far into the large bed.

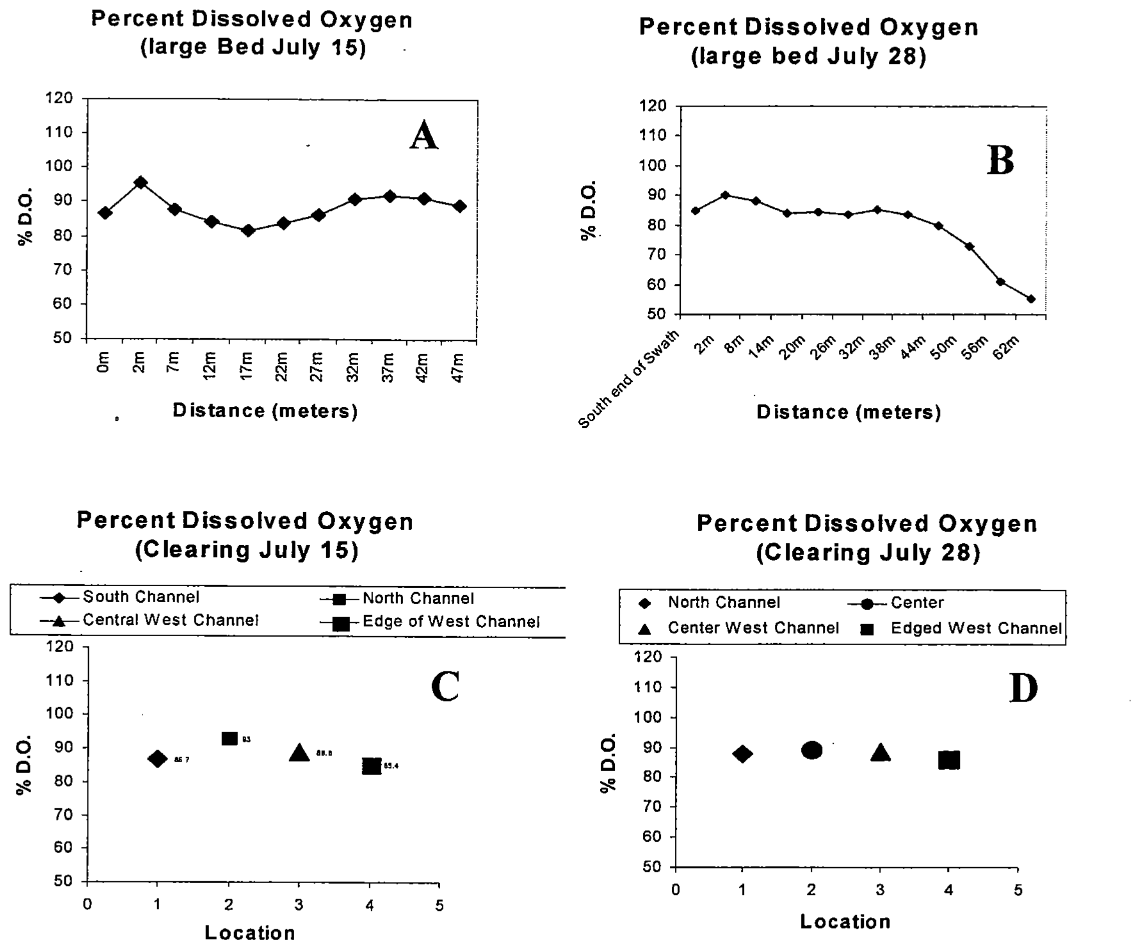


**Figure 3. Dissolved oxygen concentrations (as percent of saturation value) measured across the large *Trapa* bed and in selected parts of the cleared area. Measurements for the large bed run from the edge to the center.**

The dissolved oxygen levels along the edge bed (Figure 4a and 4b) ranged between 80-90% saturation until the edge and the main pool of the channel, in Tivoli South Bay. At the edge and main pool, the DO levels were the same as those found in the large bed and the clearing (Figure 3a-d), remaining between 80 and 90%. Readings at the boundary of the edge and the main current were more similar to the readings found at Cruger Island (Figure 4c-d). The Cruger Island site (Figure 4c-d) had higher DO levels on the edge of that bed and throughout the bed. These levels remained between 100 and 120%, decreasing further into the bed. The DO levels found in the Cruger Island site leveled off at between 100 and 110% on July 15 (Figure 4c) and between 105 and 110 % on July 28 (Figure 4d). These levels are the lowest for the Cruger Island site and between 15 and 20 percent higher then those found to be the highest DO levels in the large bed (Figure 3a-b), the clearing (Figure 3c-d) and the edge (except for the perimeter and main current; Figure 4c-d).

In addition to the spatial survey results, the submersible sondes measured the DO levels in mg/L continuously over the period of days to weeks. Unfortunately, two of the sondes (large Trapa bed and clearing) only collected data for a week, due to unexpectedly rapid consumption of the batteries (these were older sondes that were not as efficient as newer models). Nevertheless, we were able to collect some data over nearly the same 24-hour period at all sites (Figure 5). Figure 5a represents the large bed, the clearing, and the edge. Note the spike found at 18:00 and 7:00. This appears on all three of the sondes and was caused by the mixing of the waters during the changing tidal period.

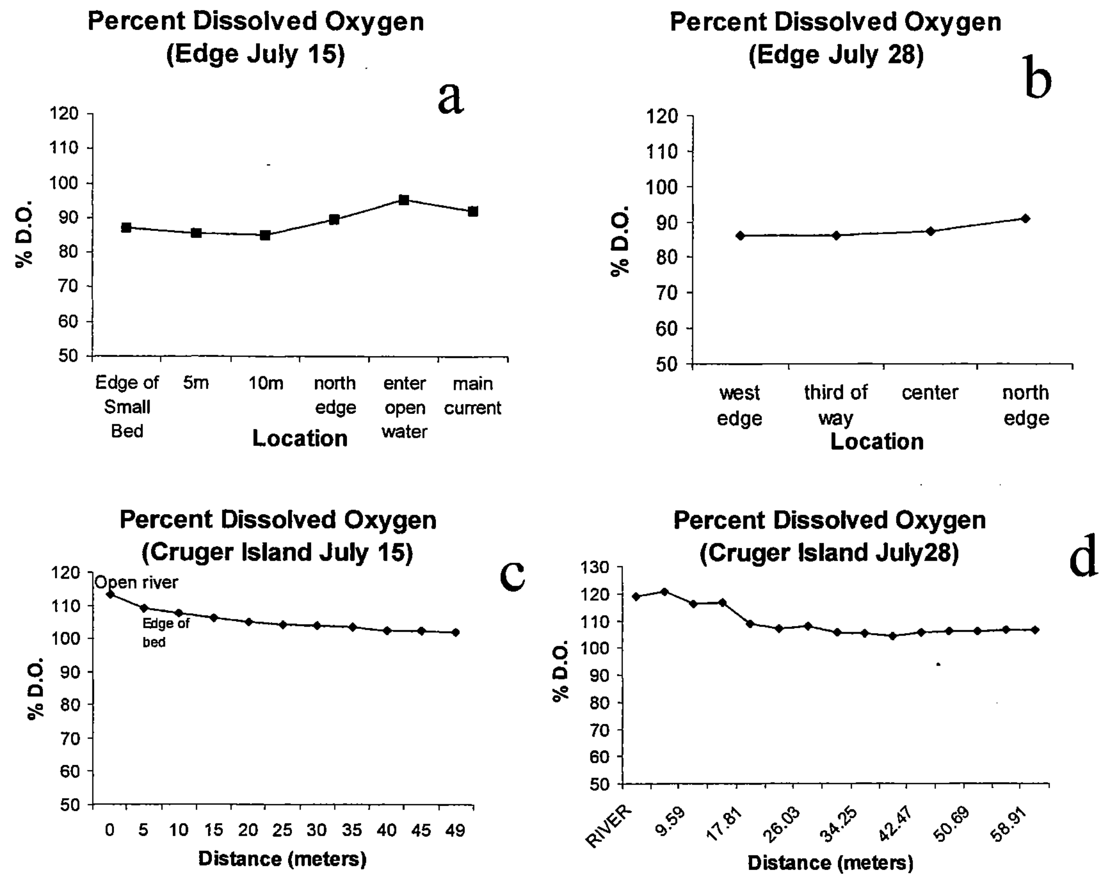


**Figure 4. Dissolved oxygen concentrations (as percent of saturation value) measured across the Cruger Island site and in selected parts of the edge site. Measurements for the Cruger Island bed run from the edge to the center.**