Effects of *Phragmites australis* on the early life history stages of *Fundulus heteroclitus* at Iona Island Marsh, Hudson River, New York

A Final Report of the Tibor T. Polgar Fellowship Program

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ABSTRACT

Phragmites australis is an invasive wetland plant impacting tidal marshes in the U.S. Physical changes (increased elevation, reduced microtopography) are accentuated in older *P. australis* stands, possibly reducing resident nekton reproduction during advanced stages of expansion. Hydrogeomorphology of different-aged *P. australis* stands and early life history stages of *F. heteroclitus* were quantified at Iona Island Marsh on the Hudson River. Triplicate treatments (large, medium, small *P. australis,* and *Typha angustifolia* (narrow-leaf cattail) patches) of varying age were sampled for *F. heteroclitus* twice monthly from June to August 2002. Patch area, distance from creek, number of rivulets, and length of aquatic edge were measured along with flooding (depth, duration, and frequency) fore each vegetation type. Mean flooding depth was higher in *T. angustifolia* relative to all *P. australis* patches. Mean flooding duration was greater in the small *P. australis* patches relative to all other treatments except large *P. australis* patches. Mean larval *F. heteroclitus* abundance in *T. angustifolia* was significantly higher compared to the large *P. australis* treatment for August. Larval fish abundance was not different between *T. angustifolia* and the remaining *P. australis* treatments, supporting the hypothesis that only larger patches experienced reduced spawning success. Larval fish abundance was associated with higher flooding depth suggesting hydrology was the primary determinant of larval fish survival. Large numbers of larval and juvenile fish was found in creek pools on low tide. Because larval *F. heteroclitus* are not normally associated with creeks, later stages of *P. australis* invasion may force nekton off the marsh surface. This may be possible in oligohaline marshes where submerged aquatic vegetation (SAV) can serve as refuge from predators on high tide.

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INTRODUCTION

Tidal wetlands are intricate components of the coastal landscape and carry out many important functions from controlling floodwaters to providing nursery and feeding habitat for wildlife (Mitsch and Gosselink 2000). All wetlands can be defined in terms of hydrology, physiochemical environment, and vegetation (Mitsch and Gosselink 2000). Often times these characteristics are in balance so that the wetland functions appropriately. In some cases, however, disturbances can negatively affect that balance and impact wetland function.

Phragmites australis (common reed) is a clonal wetland plant, which can be found throughout the world and has been a part of wetland ecosystems in the United States for thousands of years (Orson 1999). Formally a stable component of wetlands, *P. australis* has taken on invasive qualities and is more widespread in today's wetlands (Chambers et al. 1999). A recent study concludes that the expansion stems, in part, from the introduction of a non-native genetic strain (European) of *P. australis* sometime during the last 200 years (Saltonstall 2002). Expansion by *P. australis* out competes other plants including rare or endangered species (Windham and Lathrop 1999), which in turn affects the use of the wetland by many mammal and bird species (Chambers et. al. 1999). Physical changes to the marsh surface have also been documented in *P. australis*-dominated wetlands (Windham and Lathrop 1999).

After the first plant or plants are established in an area, *P. australis* spreads by vegetative growth (Tiner 1998). Its rapid growth and competitive edge allows *P. australis* to form monotypic stands (Marks et al. 1994). High production by *P. australis* also leads to accumulation of litter on the marsh surface. This accumulation contributes to an increase in elevation, flattened surface topography, and reduced flooding (Windham and Lathrop 1999).

Tidal wetland functions are primarily controlled by hydrology (Mitsch and Gosselink 2000). One function inseparable from hydrology in tidal wetlands is access to the marsh surface by resident nekton species including *Fundulus heteroclitus* (common mummichog) and *Paleomonetes pugio* (daggerblade grass shrimp). Resident nekton are defined as those fish and swimming invertebrates that occupy the marsh surface or nearby tidal creeks during most or all of their life cycle (Knieb 1984). Nekton use the marsh for feeding, egg deposition, and nursery habitat (Mitsch and Gosselink 2000). Hatching of *F. heteroclitus* is triggered by tidal synchrony, i.e. regular periodicity between spring tides (Taylor et al. 1977, Taylor et al. 1979) and larvae and small juveniles of resident nekton specifically require microtopographic depressions (small pools) on the marsh surface for low tide refuge (Kneib 1984).

Previous studies have shown that when *P. australis* marshes are adequately flooded, adult nekton utilize the marsh surface (Fell et al. 1998, Hanson et al. 2002, Able and Hagan 2000, Warren et al. 2001, Osgood et al. 2003) and in the case of *F. heteroclitus* will deposit eggs (Raichel et al. 2002). There is growing evidence, however, that larval and juvenile *F. heteroclitus* have lower abundance and density in *P. australis*-dominated marshes relative to other vegetation types (Able and Hagan 2000, Able et al. 2003, Fell et al. 2003, Meyer et al. 2001, Osgood et al. 2003). The lack of smaller size classes has been attributed to lack of microtopography on the marsh surface (Able and Hagan 2000, Able et al. 2003) and altered flooding patterns (Osgood et al. 2003) in *P. australis* marshes.

Hydrogeomorphic changes attributed to *P. australis* are more evident in larger, well established stands of *P. australis* than in smaller stands of *P. australis* (Windham and Lathrop 1999, Rooth and Stevenson 2000). Different marshes exhibit different stages of *P. australis* expansion. In marshes with higher salt and sulfur concentrations *P. australis* stands tend to occur in small, isolated patches and can occur preferentially along creek banks and upland fringes (Warren et al. 2001), while in low salinity marshes such as at Iona Island, expansion can result in contiguous large areas of *P. australis* (Chambers et al. 2002). We proposed that hydrogeomorphic differences cause variation in spawning success (the abundance of smaller size classes of resident nekton) among *P. australis* stands. Further, these differences should vary predictably with the stage of *P. australis* expansion.

Objective

The purpose of this study was to determine the relationship between the distribution of size classes of *F. heteroclitus* and the hydrogeomorphology of *P. australis* stands.

Hypothesis

Larger, more established *P. australis* stands will have a lower abundance of larval and juvenile *F. heteroclitus* on the marsh surface relative to other *P. australis* stands and *T. angustifolia*. Low larval abundance will be credited to a reduced amount of flooding resulting from higher marsh elevations.

MATERIALS AND METHODS

Site Description and Study Design

This study was carried out at Iona Island Marsh, a component of the Hudson River National Estuarine Research Reserve (Figure 1). This intertidal marsh is located on the western shore of the Hudson River and covers an area of 225 ha. Iona Island Marsh is an oligohaline marsh, comprised of *P. australis* (~70%) and *Typha angustifolia* (cattail) (~30%). Other emergent plants are located in the marsh but they are a small part of the community. Within the past 45 years *P. australis* has been expanding its populations in Iona Island Marsh (Winogrond and Kiviat 1997) and at present older and younger stands coexist.

Nekton abundance was documented within each of four marsh surface treatments, small, medium, and large *P. australis*, and *T. angustifolia* stands. The *T. angustifolia* served as a reference as it predates the *P. australis* stands. The four treatments were differentiated into triplicate patches for a total of twelve sampling locations (Figure 1). There were two requirements for each patch belonging to a single size treatment. They had to be completely covered with the designated vegetation, and they needed to have equivalent elevations (as determined through standard topographic surveying techniques).

Biotic Sampling

Marsh Surface Sampling

Nekton were sampled every two weeks, during consecutive spring tides from June 12 to August 22, totaling eight individual tidal events per treatment (Table 1). Fish were collected with eight pit traps in each patch totaling 24 per treatment. Two pit traps each

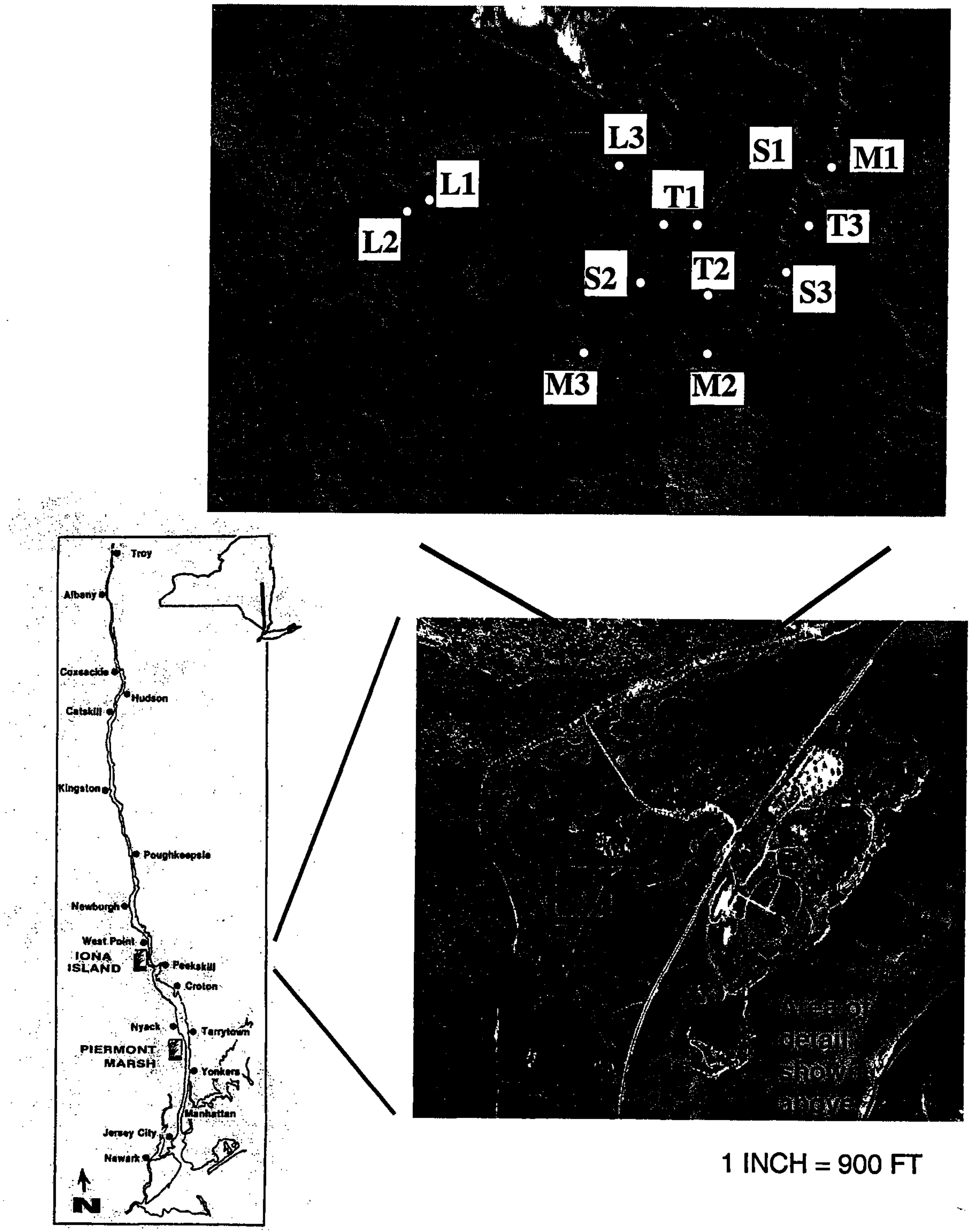

Figure 1. Site Figure of Iona Island, Hudson River, NY. Detailed inset shows location of *Typha angustifolia* (T1-T3), large (L1-L3), medium (M1-M3), and small (S1-S3) *Phragmites australis* sampling sites.

were situated at random intervals along four 15-meter transects traversing the large *P. australis* patches. Four pit traps each were situated at random intervals along two 15-meter transects traversing the medium and small *P. australis* patches as well as the *T. angustifolia* patches. The pit traps consisted of small plastic tubs (30 X 20 X 4 cm) inserted into the marsh flush with the mud surface and held in place with two PVC anchors. The pit traps were set in place on a rising tide and sampled on the subsequent low tide. On two of the trips, once in July and once in August, daytime sampling was also conducted and so there were a total of 8 collections over the course of the summer with 638 traps sampled in all. Variation in the height of the tide across the sampling dates resulted in some traps not flooding. There were also occasions when there was inadequate time to set all traps prior to high tide. These two factors resulted in some traps not being sampled (Table 1).

Other Habitats

Other habitats sampled for nekton included rivulets (small microtopographic features that connect a main creek to the marsh surface, ranging in length from 0.5 to 38 m, with a maximum width of 1 m) and pools (~ 0.5 m ID) in the main creek on low tide. Eight rivulets were sampled over the course of the tidal cycle using un-baited nylon minnow traps, one trap per rivulet. Three of these rivulets were also sampled with hoop nets (1 m ID, 3 mm mesh, 3 hoops), one net per rivulet. Four of these rivulets coincided with *T. angustifolia* patches and the other four were within *P. australis* patches. The creek pools were sampled using dip nets. Sampling of the habitats occurred on July 10, 23, and August 9.

Table 1. Total number of samples collected from each of the four treatments on each sampling date. The total samples collected over the course of the summer are also shown.

		P. australis			*T. angustifolia*
Date	Day/Night Sampling	Large	Medium	Small	
June 12	N	24	0	8	16
June 25	N	24	24	19	24
June 26	D	24	24	19	24
July 10	N	24	24	19	24
July 23	N	24	24	19	24
August 8	D	12	7	12	12
August 9	N	24	22	20	21
August 22	N	24	24	24	24
Total	---	180	149	140	169

All fish were preserved in a 5% solution of neutral formalin upon returning to the laboratory at Albright College. Samples were also stained with rose bengal to facilitate identification during sample processing. The samples were enumerated, identified, and total length measurements were taken. *F. heteroclitus* individuals less than 13 mm total length were categorized as larval, and individuals between 13 and 35 mm were classified as juvenile. Individuals greater than 35 mm were considered adults (Kneib 1986).

Hydrogeomorphic Measurements

Hydrology (flooding duration, depth, and frequency) was measured in two of the triplicate patches for each treatment. These measurements were made with the use of

PVC wells. Wells consisted of a 3 inch PVC pipe screened over the entire subsurface length (50 cm). Each well was equipped with a remote data logger and pressure transducer (resolution +/- 1.3 cm). The water level in the well was measured every 24 minutes for 30 days from late May through July. Additionally, 15 days of measurements were made in August at 12-minute intervals. These measurements resulted in a total of 96 recorded high tide events for each instrumented patch. Pressure readings recorded by the transducer were converted to water level by calibrating each instrument with measurements of actual water level in the wells. The manual measurements of water level are done concurrent with pressure transducer recordings from the data logger in the field. Water level was manually measured with a Hydrolite® water level recorder (Environmental data systems, Inc.). Water levels are expressed as the average flooding depth (cm) and as average flood duration (hours tidal cycle^{-1}) over all recorded high tides. Flooding frequency is reported at the percent of high tide events per month that the marsh surface was flooded.

Patch sizes were determined by delineating the perimeter of each *P. australis* patch and the *T. angustifolia* areas using a Trimble ProXR® GPS accurate to 1 m in length (Trimble Data Systems, Inc). The GPS was also used to delineate the main creeks, rivulets, and placement of wells and pit traps. The GPS data were used to enumerate patch area, distance from patch edge to the nearest creek, distance from the center of the pit trap array to the nearest creek, number of rivulets per patch, and the total aquatic edge (water/marsh boundary) per patch.

Statistical Analysis

Differences in abundance of larval and juvenile *F. heteroclitus* among the vegetation treatments were tested using Analysis of Variance (ANOVA). Assumptions of normality and equivalent variance measurements were satisfied on data pooled over all sampling periods. Data were also analyzed for each month using ANOVA. A discriminant analysis was used to analyze the variation of the hydrogeomorphic variable among the four vegetation treatments. Regression analysis was used to compare flooding depth and duration to fish abundance.

RESULTS

Resident Nekton

The mean monthly abundance of larval *F. heteroclitus* is shown in Figure 2. Significant differences were only found in the month of August. The *T.* angustifolia mean larval abundance and small *P. australis* treatments (3.56 and 1.89 individuals, respectively) were significantly higher than the large and medium *P. australis* treatments in August ($P < 0.05$). The small *P. australis* treatment mean larval abundance in August was also significantly higher (1.89 individuals) than the large and medium *P. australis* in August and all other treatments for other months. There were no differences in mean abundance between *T. angustifolia* and small *P. australis* treatments in August.

Only three treatments yielded juvenile fish and all were caught during the August sampling dates. These were the large *P. australis* (mean = 1.22, S.E. = 0.91), small *P. australis* (mean = 0.222, S.E. = 0.222), and the *T. angustifolia* (mean = 0.111, S.E. = 0.111) treatment. Large *P. australis* juvenile abundance was significantly greater than all other treatments ($P < 0.05$).

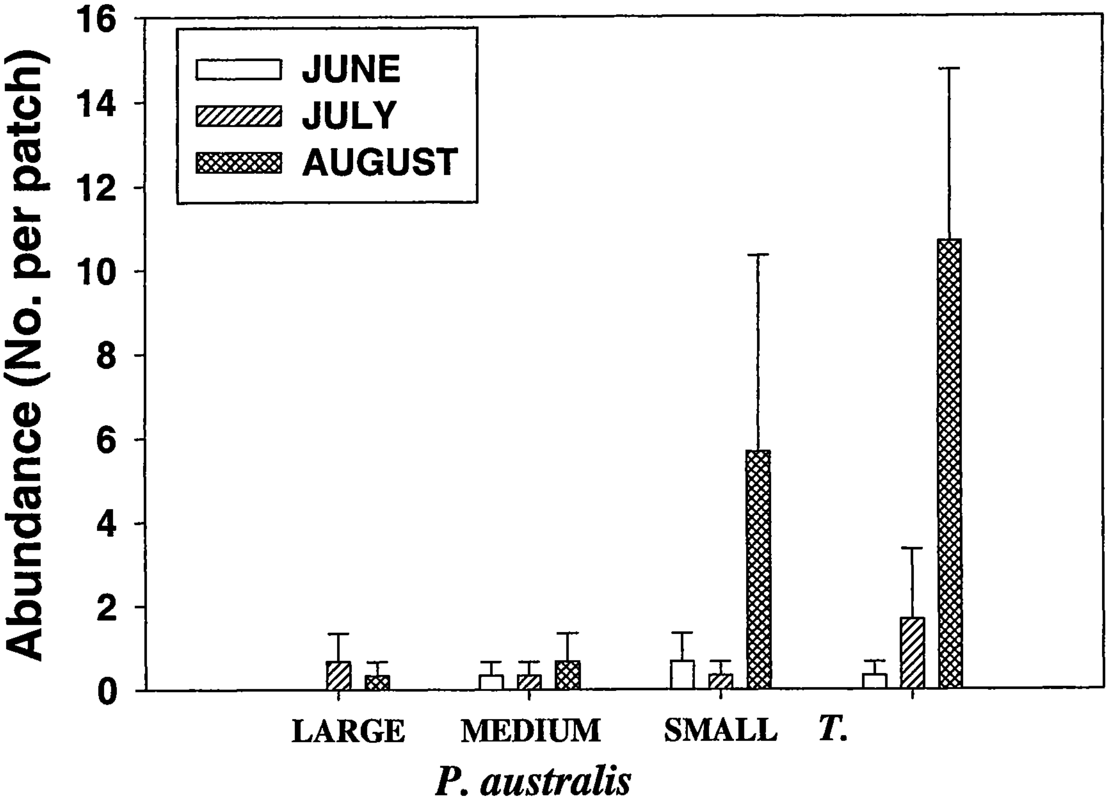

Figure 2. Abundance of larval (< 13 mm total length) *Fundulus heteroclitus* (common mummichog) collected from June-August 2002. Bars represent the average of the total number per patch. Error bars indicate standard error of the mean. (n = 3 patches per treatment, 8 traps per patch)

Figure 3 shows the mean abundance of larval, juvenile, and adult *F. heteroclitus* captured in all three sampled habitats. A large abundance of larval and juvenile fish were caught in pools of the main creek on low tide, while adults were dominant in rivulets sampled throughout the tidal cycle. As indicated above larval size classes followed by juvenile and a few adults dominated the marsh surface. These data were collected to catalog the presence of different size classes among the habitats and were not subject to statistical analysis. In addition to *F. heteroclitus*, the hoop nets also yielded a number of *Morone saxatilis* (striped bass), *Morone americana* (white perch), and *Anguilla rostrata* (American eel).

Hydrogeomorphology

The mean depths and duration in each of the treatments over the sampling period are shown on Figure 4. The mean depth of flooding in the *T. angustifolia* treatments was significantly higher than the other three treatments ($P < 0.05$). Flood duration for the small *P. australis* treatment was significantly greater than for all other treatments except the large *P. australis* treatment. Flooding frequency (percentage of high tide events during the month that the marsh surface was flooded) was higher in the small *P. australis* and *T. angustifolia* treatments relative to all other treatments.

The discriminant analysis (Figure 5) revealed that the geomorphic characteristics among the *T. angustifolia* and large *P. australis* treatments grouped together. At the same time, the small and medium *P. australis* treatments were more similar to one another and distinct from the other two treatments. This separation occurred primarily along the Variate 1 axis of the canonical scores plot (Figure 5) where there was 86.8% of

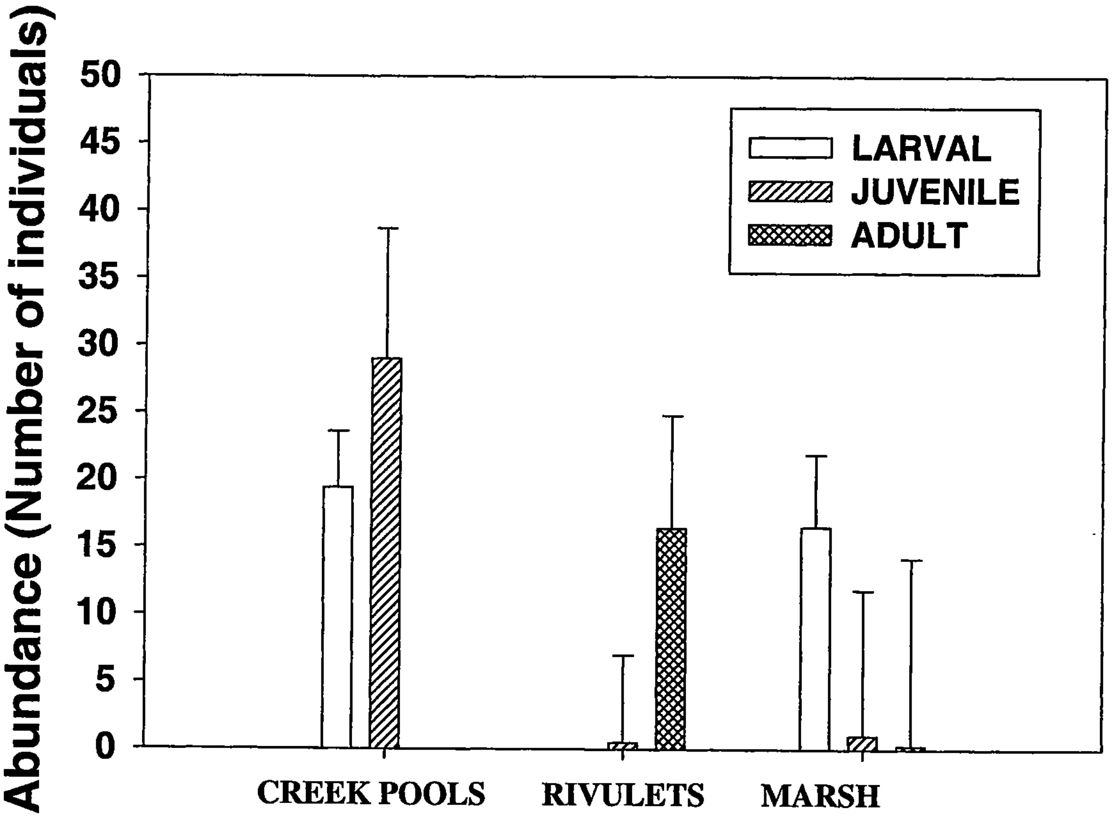

Figure 3. Average number of *Fundulus heteroclitus* caught in three subhabitats at Iona Island Marsh. Larvae (< 13 mm TL), Juvenile (13-35 mm TL), and adult (>35 mm TL) size classes are differentiated. Sampling in creek pools and rivulets was conducted in July and August 2002. Marsh surface value is the grand mean of all treatments from July – August 2002. Error bars represent standard error of the mean.

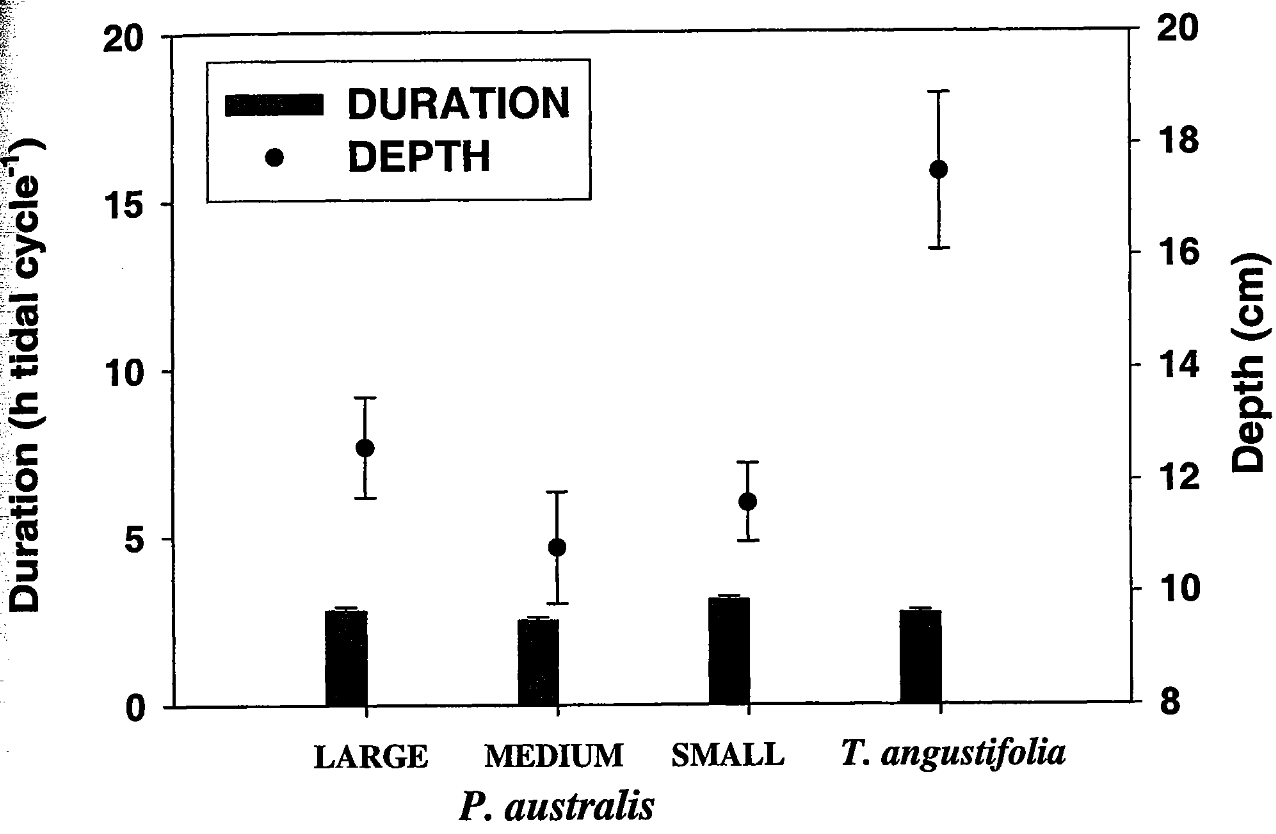

Figure 4. Average depth and duration of flooding at Iona Island Marsh. Mean represents data collected from two patches for each of the four vegetation treatments over 30-day periods during June and July and a 15-day period in August 2002. Error bars represent standard error of the mean.

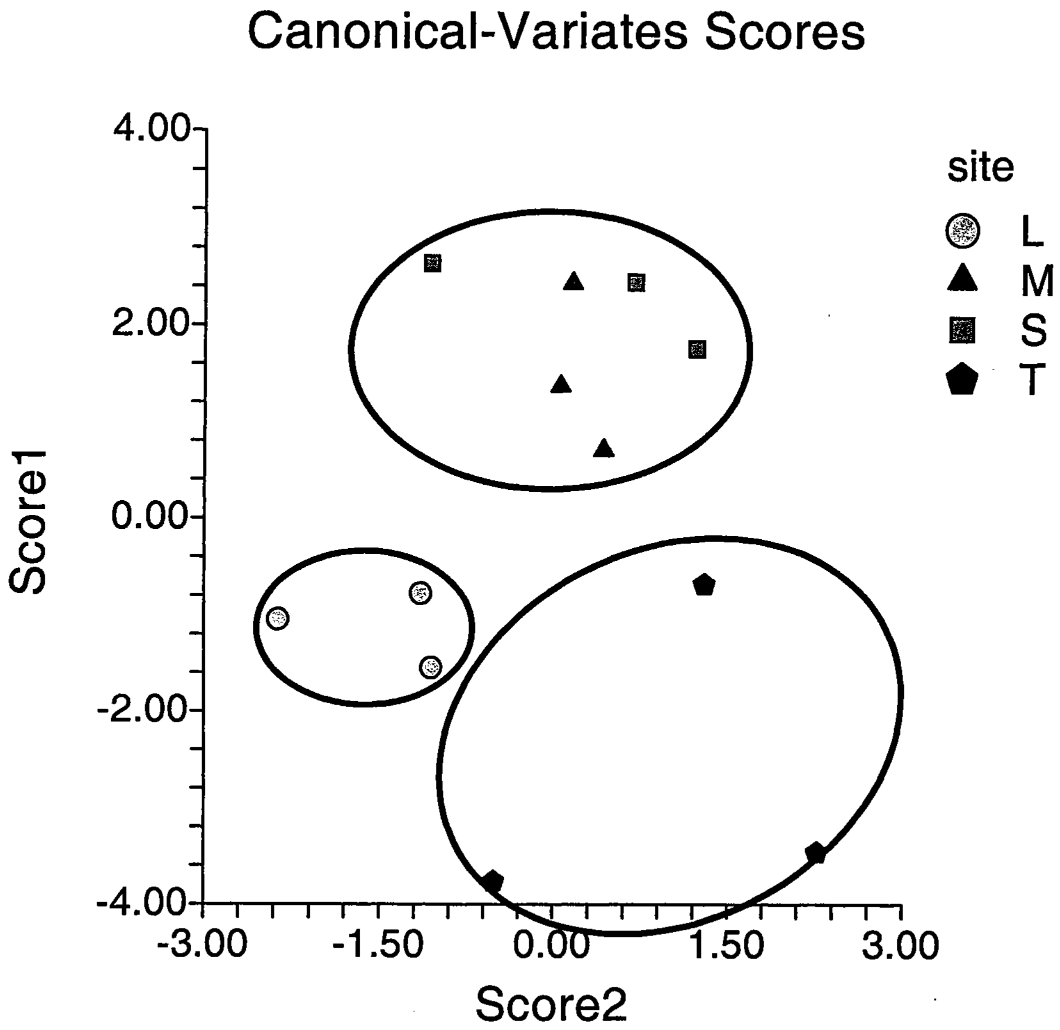

Figure 5. Canonical score plot from a discriminant analysis of geomorphology of three patches each across the four vegetation treatments. Refer to Table 3 for standardized canonical coefficients for each geomorphic variable.

the variation among patches. Another 11.9% of the variation occurred on the Variate 2 axis. Area was obviously the primary variable explaining separation among the patches (Tables 2 and 3). Total rivulet length and number of rivulets were the source of the next largest variation separating the patches (Table 3). Large *P. australis* and *T. angustifolia* were associated with shorter, but more numerous, rivulets relative to the medium and small *P. australis* patches (Table 2). Both large *P. australis* and *T. angustifolia* patches were also ranked together based on similarly high elevations and were closer to creeks with a greater length of total aquatic edge. These latter variables, however, explained the least amount of variation between the patches.

Table 2. Standardized Canonical Coefficients from the discriminant analysis of individual patches of *Phragmites australis* and *Typha angustifolia* at Iona Island. See Figure 5.

Variable	**Canonical Variates**	
	Variate 1 (86.8%)	**Variate 2 (11.9%)**
Area	**-1.95**	**0.10**
Total Rivulet Length (m)	**1.60**	**-2.01**
Number of Rivulets	**-1.21**	**-0.43**
Elevation (m)	**-0.97**	**-0.33**
Distance to Creek (m)	**0.83**	**-0.52**
[1]Total Aquatic Edge (m)	**-0.74**	**1.36**

[1] Includes length of rivulets and creeks

The results of the regression analysis are plotted in Figures 6 and 7. Average flooding depth over the study period (broken up by patch) was positively related to mean larval abundance over the study period ($P < 0.05$). In contrast, average flooding duration was not significantly related to larval fish abundance.

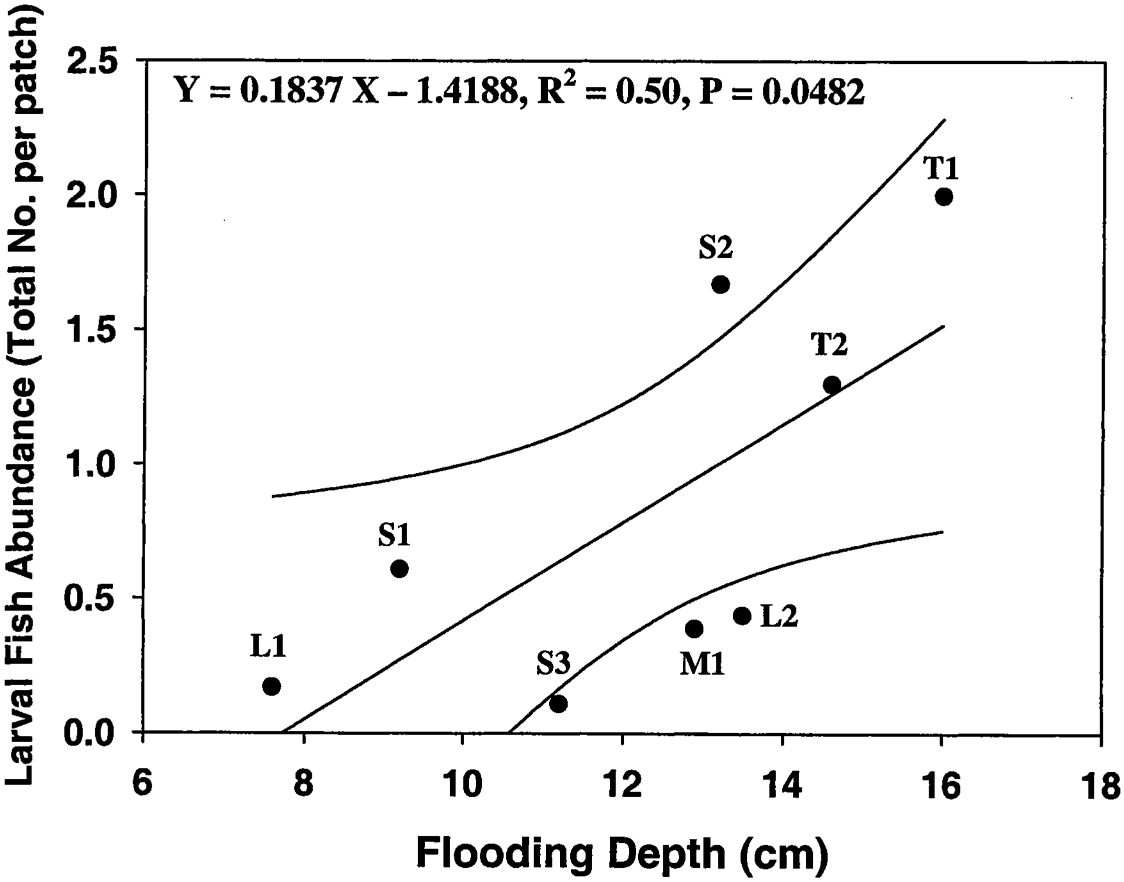

Figure 6. Regression analysis results of comparison between larval fish abundance and flooding depth as a function of individual patches within each vegetation treatment, *T. angustifolia* (T1, T2), small (S1, S2), medium (M1, M2), and large (L1, L2) *P. australis*. Flooding depth is the average from June-August 2002. Fish abundance is the total number caught for that plot over the course of the study.