1-30-2010

Evaluation of Post Restoration Conditions at Little River Marsh in North Hampton, New Hampshire

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Final Report
January 30, 2010

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Executive Summary

The goals of the restoration project at Little River were two-fold: 1) restore ecological function of the marsh by reestablishing regular tidal flooding; and 2) reduce the frequency and severity of local flooding to surrounding landowners. Our report documents substantial progress toward the first goal using regional monitoring protocols to assess four functional areas: hydrology, soils, vegetation and nekton. Installation of two large box culverts (each 1.8 by 3.6 m in cross-section) greatly enhanced tidal flow and freshwater drainage. The tide range increased from 0.5 to 1.4 m during spring tides and now even neap high tides flood most of the marsh surface.

The marsh has responded to the increased tidal exchange. In the year following installation of the culverts, soil salinity increased and became similar to levels found at Awcomin Marsh, which was used as a reference site. The marsh vegetation has shown steady changes, including increased native halophytes and decline of invasive plants, so that after five years the cover of halophytes, brackish plants, and invasives are similar to those found at Awcomin Marsh. Little River Marsh shows a clear trajectory towards establishment of a functioning salt marsh system. However, changes are likely to continue as the full range of ecological functions and values become realized at this site.

Acknowledgements

Post-restoration data collection and reporting were funded by the New Hampshire Coastal Program under grant number NA 17FZ2603 from the Restoration Center of the National Atmospheric and Oceanic Administration (NOAA). In addition, we are appreciative of the town of North Hampton, Geoff Wilson of Northeast Wetland restoration as well as many federal and state agencies, including the Natural Resource Conservation Service and the US Army Corps of Engineers for their leadership and cooperation in the restoration effort.

We are grateful to the New Hampshire Coastal Program, Jackson Estuarine Laboratory, for their cooperation and support of this experiment. We are also appreciative of the field assistance from Catherine Bozek, Alyson Eberhardt, Ray Konisky, Jessica Smith, and Kirsten Nelson of UNH, Ted Diers, Jen Drociak, Elizabeth Jones and Beth Lambert of NHCP, Brandi Bornt of Ducks Unlimited and several citizen volunteers as part of the NH Marsh Monitors.

Cite as: Burdick, D. M., R. Vincent and C. R. Peter. 2010. Evaluation of Post-Restoration Conditions at Little River Marsh in North Hampton, New Hampshire. Final Report to: the New Hampshire Coastal Program, Portsmouth, NH.

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Introduction

Since the early 1990s, tidal restrictions from roads, railways, and earthen berms have been recognized to cause severe impacts to the ecological structure and functioning of salt marshes (Roman et al. 1984, Burdick et al. 1997). For example, tidal restrictions have led to the proliferation of brackish and invasive exotic plants such as common reed (*Phragmites australis*) and purple loosestrife (*Lythrum salicaria*), prevented fish access and eliminated essential fish habitat, and promoted insect pests such as mosquitoes (Burdick et al. 1994, Neckles et al. 2002, Raposa and Roman 2003).

Little River Marsh is a back barrier marsh, approximately 200 acres in size, located within the Towns of Hampton and North Hampton. The marsh has a long history of problems associated with its inlet to the Gulf of Maine (Ammann et al. 1999). Little River Marsh has been effectively cut off from normal tidal flow by Route 1A. Over the past three decades, all tidal flow passed through a round, 48 –inch (1.2m) culvert running under Route 1A at the northern end of the marsh (Figure 1). Inadequate size of the culvert was blamed for flooding during snowmelt in spring and extreme rainfalls that flooded basements and some first floors of homes surrounding the basin. Further development has resulted in two causeways (Appledore Road and Huckleberry Road) that were built across southern portions of the marsh to access residential homes on islands within the marsh. The site was categorized as impacted by tidal restrictions in a survey of coastal marshes (USDA 1994). Personnel from several agencies agreed that the system had been negatively impacted from tidal restriction and was in need of restoration (New Hampshire Coastal Program (NHCP), NOAA Restoration Center, US Fish & Wildlife Service (FWS), Natural Resource Conservation Service (NRCS) and US Army Corps of Engineers (ACOE)).

The NHCP and the Town of North Hampton, aided by state and federal officials and in cooperation with local landowners, proposed to replace the existing culvert with two larger culverts. The project had two major goals: reduce spring flooding of abutting property owners and restore ecological function to the tidal marsh by increasing tidal exchange. Two 6-foot by 12-foot (1.8 by 3.6 m) box culverts were installed side-by-side in November 2000.

Figure 1. Old and New Culverts: upper photograph shows outlet (Gulf of Maine side) of the original 1.2 m (48-inch) culvert; pictured below is the marsh side of the new culvert (two side-by-side 1.8 by 3.6 m or 6 by 12 foot culverts).

In addition, the artificial creek serving the inlet was widened 7.2 meters (24 feet), where needed, to match the width of the new culvert. The section of creek proximal to the culverts was also deepened and a low dam was found and strengthened to retain water in the main creek to enhance fish habitat. Further, several deeper pools were excavated along main tidal creeks to provide low tide refugia for fish. Other activities were also performed to enhance marsh function. A side creek was plugged to ensure water flow along the main creek, and secondary creeks (ditches) draining large panes on the eastern flank of the marsh were plugged. With the improved tidal flow under Route 1A, the larger culvert under Appledore Road provided additional flow to the southern reaches of the Little River Marsh.

In anticipation of the tidal restoration, NHCP organized and led a monitoring effort to collect data characterizing conditions within the degraded marsh and enlisted researchers at Audubon Society of New Hampshire (ASNH) and Jackson Estuarine Laboratory (JEL) to assist in data collection and analysis. Pre-restoration data on hydrology, soil salinity, vegetation, fish and birds were compiled and reported (Burdick 2002). Subsequent to the installation of the new culvert, JEL researchers monitored hydrology, soils, vegetation and fish to assess how the site was adapting to the new tidal regime.

Methods

The restoration effort at Little River was coincident with development of standardized protocols to determine restoration outcomes. In 1999 a regional meeting of salt marsh experts was convened and protocols were published in 2000 (Neckles and Dionne 2000). These experts recommended sampling at the restoration site and a reference marsh both before and after construction, termed a Before/After Control/Impact (BACI) design. They also recommended indicators for five core functional areas: hydrology, soils, vegetation, fish and birds. We collected data using the BACI design for hydrology and salinity. Pre-restoration vegetation data for the reference marsh were not available and post-restoration transects for Little River were expanded. Due to restricted flooding of the impacted marsh and limited sampling methods, pre-restoration fish sampling that produced density-dependent data was limited; most sampling was done after the culvert installation.

Hydrology:
Tidal signals at Little River and its reference, Awcomin Marsh, were measured before and after restoration over spring-neap cycles. At Little River, the gauge was set up about 150 meters from the culvert; after the first bend of the 'trunk', which was widened for restoration (Figure 2). At Awcomin, the gauge was set up in an old tidal creek just west of the Route 1A bridge, about 100 meters from the inlet to Rye Harbor (Figure 3).

Figure 2. Hydrology (H) and salinity well stations (1-8) at Little River Marsh. Image is from Google Earth.

Figure 3. Hydrology (H) and salinity well stations (1-5) at Awcomin Marsh, the reference site. Image is from Google Earth.

Prior to restoration, the water level was determined by sonar (Infinities USA) and recorded every 10 minutes October 26 to November 20, 2000. After restoration water levels were determined using a new capacitance-based sensor (Odyssey) at 10-minute intervals October 26 to November 26, 2006. Spring and neap tide heights were calculated by averaging maximum water heights recorded by data loggers approximately 3-5 of the highest tides, respectively. A very large tide on October 28th (likely associated with a storm) was recorded at both locations, but not used in the analysis.

To determine the amount of flooding of the marsh a hypsometric curve was created. Spot elevations were recorded at each vegetation plot and other key locations using a laser level and rod. Data for hydrology and elevations were tied into NGVD using pre-determined benchmarks located on or near the project site (Huckleberry Road for Little River; Rye Harbor culvert for Awcomin). These data help to illustrate the percentage of marsh flooded for a given tidal height. When available, details regarding the projected change in tidal elevation and surface area footprint of pre- and post-restoration conditions were noted.

Soil Salinity:

Soil salinity is a critical indicator of tidal restrictions since they impede saltwater flow into marshes as well as fresh water flow exiting marshes. In addition, soil salinity is an important stress (like flooding) that structures the plant community of coastal marshes. The interstitial water of the sediment was collected from wells and salinity was measured using a hand-held optical refractometer (± 1 ppt with automatic temperature correction). The wells were made from PVC pipe with a series of holes (3 mm in diameter), extending from 5 to 20 cm deep in the marsh sediment. The wells were sealed at the base and fitted with two 90° bends at the top to prevent rain and flood water from entering.

Wells were installed at eight stations in Little River Marsh and five stations at the reference marsh (Awcomin Marsh). The well pattern at Awcomin Marsh followed the standard protocol (Neckles et al. 2002), but the pattern at Little River Marsh was modified. Sites were added to accommodate the southern portion of the Little River as it flowed under Appledore and Huckleberry Roads toward the original tidal inlet that is now sealed (Ammann et al. 1999).

At Little River, pre-restoration salinity samples were collected between August 1999 and September 2000 and post-restoration samples were collected between April 2001 and August 2005. Salinity samples were also collected at Awcomin Marsh May 2001 to August 2005 (post-restoration). Sampling dates ere chosen to include both spring and neap lunar tidal periods.

Vegetation:
Emergent plant communities in the marsh were assessed using stations along permanent transects. Vegetation was assessed using quadrats (0.25 m^2 sampling area in 1999 - 2001 and 0.5 m^2 in 2002 to 2005) placed every 15 meters (Neckles et al. 2002). Vegetation surveys recorded percent cover of all observed plant species. Additional measurements were recorded for invasive species identified as species of concern: common reed and purple loosestrife *(Lythrum salicaria)*. These species were measured for stem density (number of stems per quadrat) and stem height (height of the three tallest individuals) as recommended by the regional protocol (Neckles and Dionne 2000).

Nekton:
Fish were sampled prior to hydrologic restoration in 1999 using minnow traps and seines and again in 2000 using minnow traps and throw traps. Minnow Traps were deployed for 90 minutes in panes and creeks. The seine used was 3.7 m wide with 6 mm mesh. Seining was done in a moderate-sized creek with hard bottom near the Route 1A culvert, and distance fished was recorded. The throw trap was square and 1m on each side with 3 mm mesh according to Kushlan (1981). Pre-restoration fish results are reported previously (Burdick 2002), but only throw-trap results are presented here because they provided fish density data. Large aquarium nets were used to collect captured fish and all fish were considered taken following 10 consecutive empty sweeps. After restoration in 2003 and 2005, fish use in Little River and Awcomin were assessed following standardized protocols (Drociak and Bottitta 2003). Lift nets were captured fish in pools and pannes while ditch nets were used in ditches and creeks.

Once collected, all fish were held in buckets until identified to species and measured. The first 30 fish of the same species captured within each sample were measured (Neckles and Dionne 2000), for length (fish board) and volume (by displacement using a graduate cylinder). Shrimp were enumerated but not measured and crabs were measured for carapace width. All animals were returned to the site of capture within about 30 minutes.

Data Analyses:
Statistical analysis was conducted using JMP statistical software, and a standard limit for statistical significance was set at probability of less than 0.05. Data were examined and transformed to satisfy the assumptions of the general linear model (independent samples, normal distributions, linear relationships, no extreme outliers or leverage points, and equal variance). Salinity data were not transformed; ranked average vegetation data were used; and nekton data were log transformed prior to analysis.

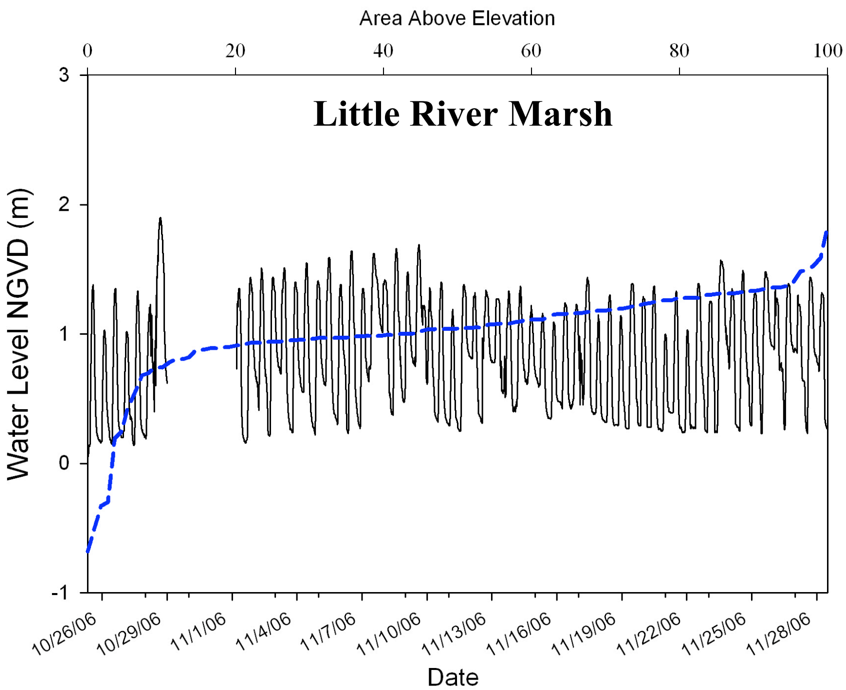
Results

Hydrology:
Under pre-restoration conditions when tides had to flow through the partially blocked 48' culvert, the spring tide range was about 55 cm (22 inches) at the trunk and only 20 cm (8 inches) at Appledore Road (Burdick 2002). In contrast, the new expanded culverts supported a much greater tidal range of about 1 meter (40 inches) during neap tides and 1.4 meters (56 inches) during spring tides (Figure 4a). Unfortunately, mud and moisture in the stilling tube prevented the WLR from correctly measuring low tides (usually at night), so many low tides show false water levels. We assumed low tide typically reached similar depths every tide.

At Awcomin Marsh, the neap tidal range averaged 1.4 meters (56 inches) for the lowest neap tides and 2.0 meters (78 inches or 6.5 feet) for the highest spring tides (Figure 4b). A large part of the difference in tidal range between the two sites is due to the Little River Marsh being perched at higher elevations behind the barrier beach system. To understand whether the present culvert limits tidal exchange at Little River, we need to examine different parts of the tidal record and compare values to our reference site. Spring tides at Little River reached about 1.7 m and at Awcomin reached 2.0 m NAVD, suggesting the new expanded culverts still restrict a portion of the highest spring tides. Neap tides showed less restriction: the small tide on October 26th 2006 was 1.0 m at Little River and 1.1 m at Awcomin (Figure 4). The maximum spring tide average at Little River is limited to a range from 2.0 meters at high tide (from Awcomin data) to 0.2 meters at low tide. So, to calculate the degree of tidal restriction remaining, we divide actual range by potential range: 1.4 / 1.8 = 0.78, which means that 78% of tidal potential was measured at Little River for spring tides and 91% for neap tides (1.0 / 1.1 = 0.91).

Superimposed on the tidal data is the marsh elevation data arranged from lowest to highest elevation: the hypsometric curve. At Little River, we see the tidal creeks represented at the lowest elevations to about 0.5 meters NAVD, and 0.9 to 1.2 meters encompasses most of the broad flat plain of the marsh, about 80% of the area (Figure 4a). When the average neap and spring tidal heights are superimposed on the hypsometric curve, we can see that most of the marsh is flooded on neap tides and virtually all the marsh is flooded on spring tides at Little River (Figure 5a). In comparison, neap tides only flood about 20% of the Awcomin Marsh area, mostly flooding creeks and low marsh (Figure 5b). In addition, a comparison of the two hypsometric curves show that the chronic tidal restriction at Little River has resulted in less topographic relief (the marsh plain elevations occur over a smaller elevation range), and the broad flat areas of the marsh are slightly lower in elevation. For example, the 50% point on the hypsometric curve for Little River is about 1.1 meters NAVD while at Awcomin Marsh it is 1.6m (Figure 5).

a.



b.

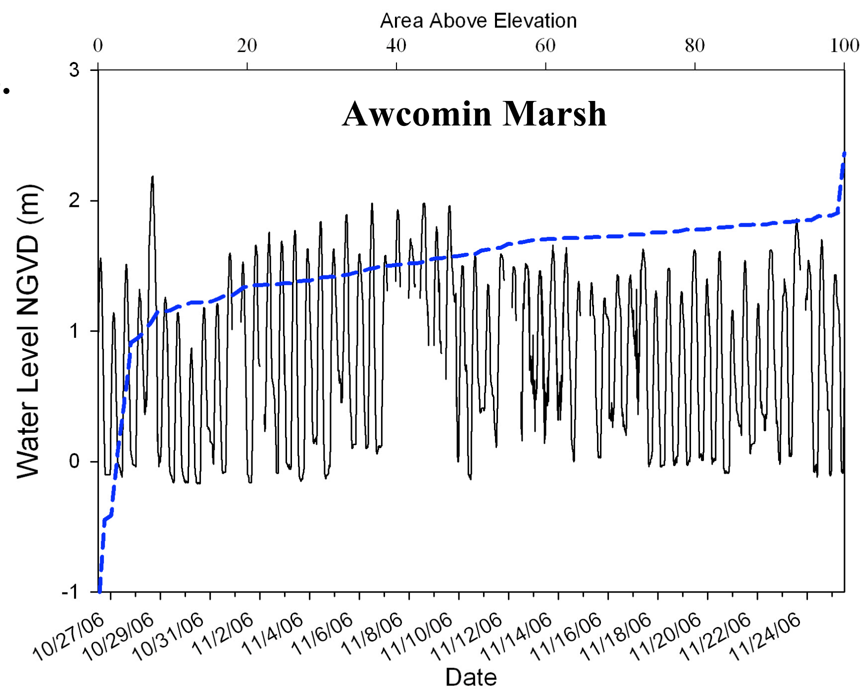


Figure 4. Tidal and hypsometric curves for: a. the restored Little River Marsh, and b. reference Awcomin Marsh relative to NADV.

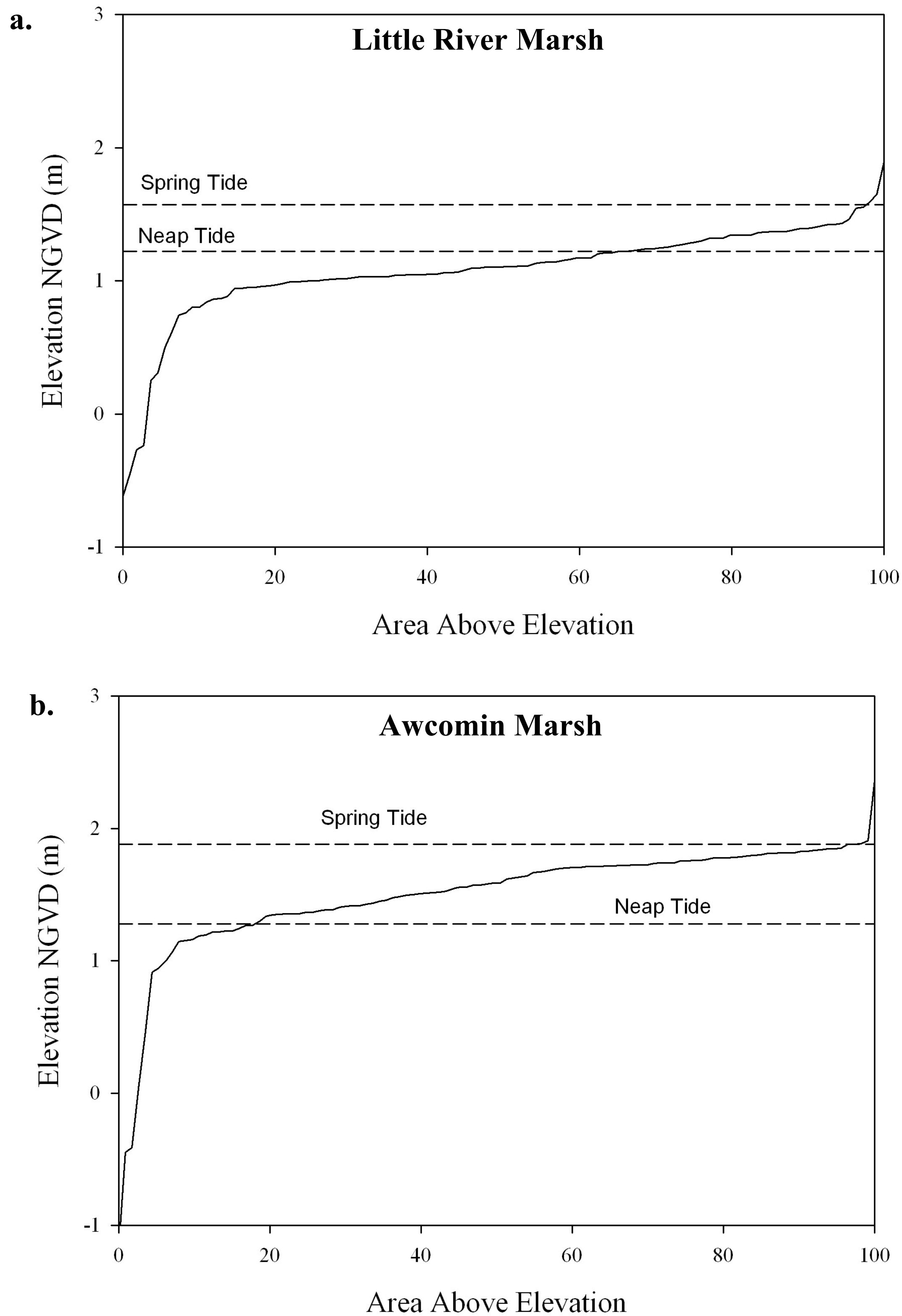


Figure 5. Hypsometric curves with average high tides for neap and spring periods: a. the restored Little River Marsh, and b. reference Awcomin Marsh relative to NADV.

Salinity:

Prior to restoration, annual soil salinity means for years 1999 and 2000 averaged 18 parts per thousand (ppt) at Little River (Figure 6). Annual variation in salinity was evident at both reference and restoration sites, but no significant difference was found between the two years of pre-restoration data ($p = 0.0894$). Average salinity increased steadily the first three years following restoration (2001 through 2003) and averaged 28 ppt, a 50% increase we can attribute to tidal restoration ($p = 0.0001$; Figure 6). Furthermore, the post-restoration salinity level and pattern of variation was similar to that of the reference site during the post-restoration period. The reference marsh at Awcomin showed no significant difference in average annual salinity from 2000 through 2005 ($p = 0.5836$).

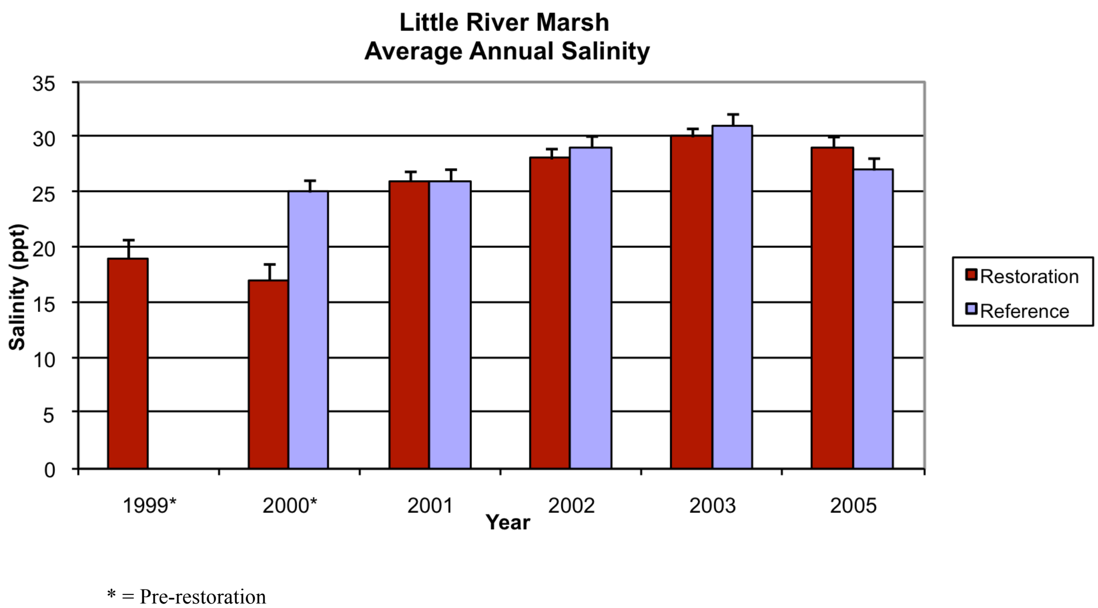


Figure 6. Average salinity per year for reference and restoration sites.

Vegetation:

Pre-restoration vegetation data were collected in 1999 at Little River, but the transects were shorter and focused on the healthier portions of the marsh. Even so, cover of brackish plants averaged 16%, about half of which was *Phragmites* and *Lythrum* (species of concern). Halophytes averaged almost 60% cover and the 'Other' category, which includes dead plants, bare soil or water, wrack and algae, averaged 24% in 1999.

Due to the shift in sampling further into fresher portions of the marsh, post-restoration vegetation analysis focused on changing conditions in Year 1, 3 and 5 (2001 to 2005; Figure 7). After restoration, it appears that brackish and invasive plants as well as some halophytes died off as the system adjusted to the new flooding regime. The major components of the 'Other' category, open water and bare soil increased through Year 3, but then fell by Year 5. In contrast, by Year 5 following restoration, halophytes increased significantly (t-Test), while *Phragmites* and *Lythrum* continued to decline (Figure 7). In fact, only three plots contained *Phragmites* and none had *Lythrum* in 2005. No significant difference was observed for 'Brackish' vegetation cover among all three years post-restoration.

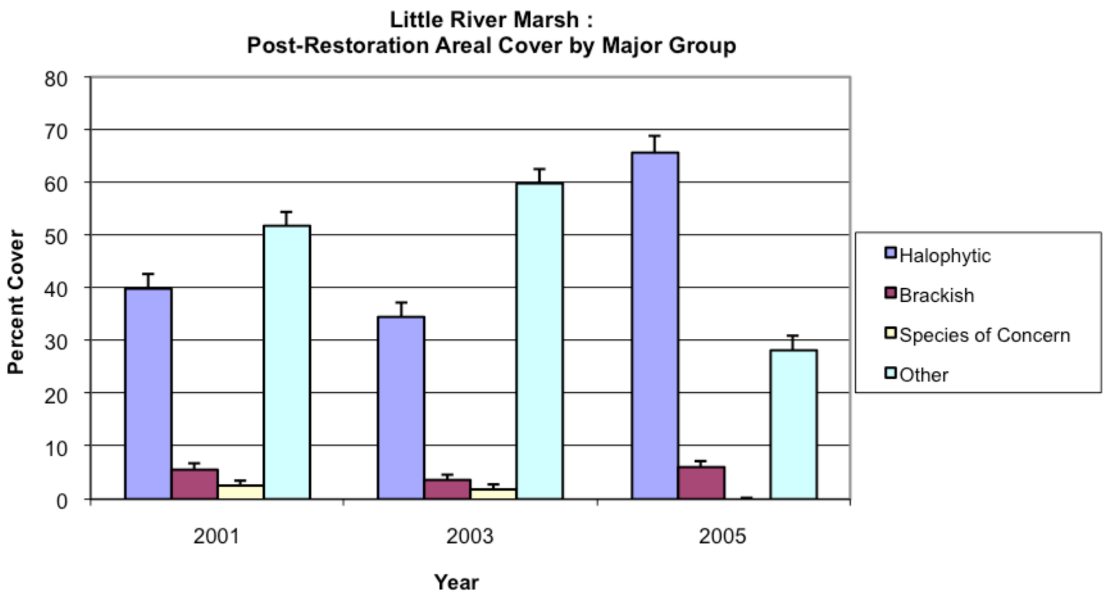


Figure 7. Areal cover per year for the Little River Marsh restoration site.

Plant cover at the Awcomin Marsh reference site was stable during the 3 years sampled, with halophytic vegetation dominant throughout the sampling period, averaging 66% cover. The 'Other' group, consisting of bare ground, open water, dead vegetation, algae, and wrack, was the second most dominant cover type (29%). Bare ground and dead vegetation were the largest components of 'Other' category. Brackish vegetation cover was minimal (averaging <5%), and species of concern were uncommon in the reference area of Awcomin Marsh (Figure 8). A comparison of each major cover type by year showed no significant change in areal cover at the Awcomin reference site over time (p>0.48).

The temporal patterns of plant cover at Little River were similar to the reference site; even though the absolute values differed. For example, halophyte cover fell from 2001 to 2003, but increased in 2005 at both reference and restoration sites (average 66% and 47%, respectively), while the "Other" category showed an increase from 2001 to 2003, dropping in 2005 at both sites (average 29% and 47%, respectively). However by Year 5, the absolute values of the categories became similar, with halophytic vegetation becoming dominant at the restoration site in 2005 (Figures 7 and 8).

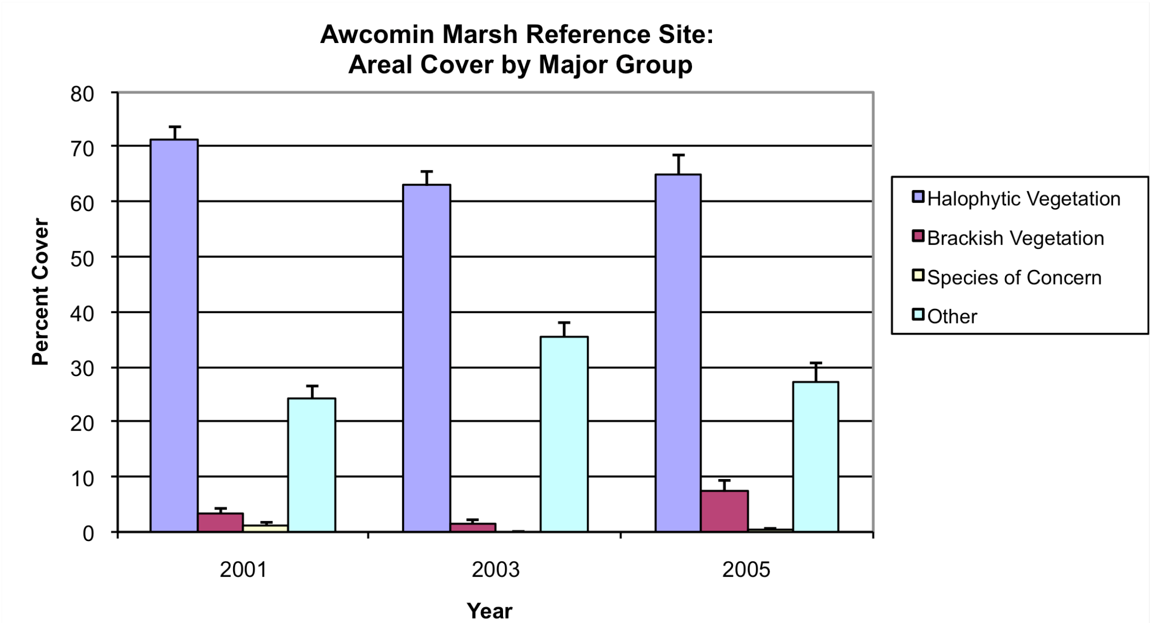
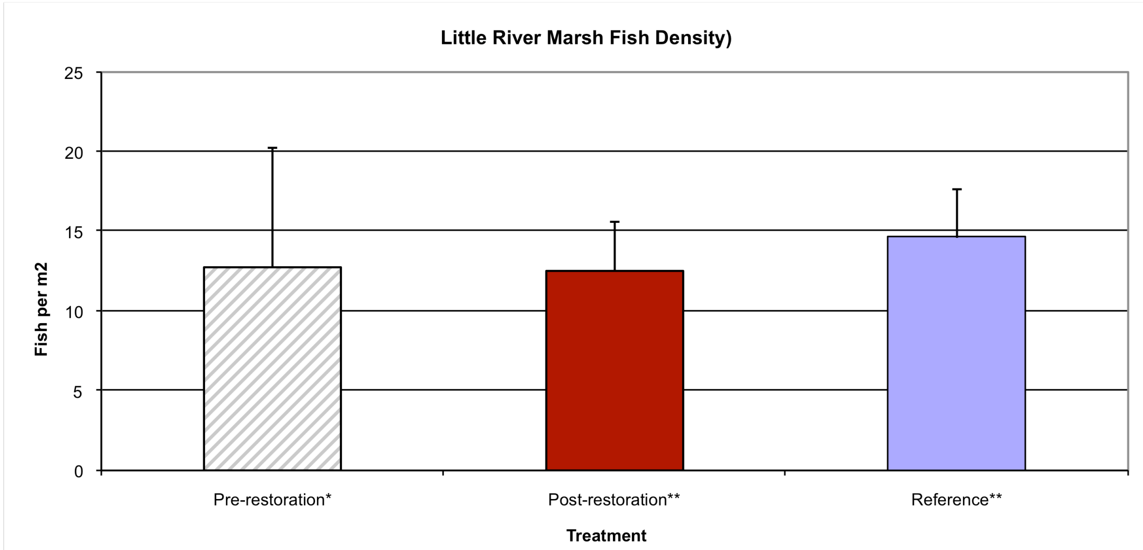


Figure 8. Areal cover for the Little River reference area at Awcomin Marsh.

Nekton:

Nekton are fish and crustaceans that are found in the water column. Pre-restoration sampling for nekton took place at the Little River restoration site during 2000, and an average of 12 fish m^{-2} were captured using throw traps, all mummichogs (*Fundulus heteroclitus*). Post-restoration sampling was conducted during the years 2003 and 2005 at reference and restoration sites using lift and ditch nets with catches averaging between 12 and 15 organisms m^{-2}. No significant difference was observed among pre- and post-restoration fish densities at Little River or between Little River and Awcomin Marsh following restoration with years averaged (Figure 9).

A comparison of within-year fish densities among post-restoration and reference sites showed non-significant differences in fish densities during the two years sampled ($p = 0.6667$, for 2003; $p = 0.4226$, for 2005) (Figure 10).



* = 2000; ** = 2003 & 2005

Figure 9. Nekton density per treatment area for years 2000, 2003 and 2005. Pre-restoration data were collected using a throw trap; post-restoration data were collected with lift nets (pools and pannes) and ditch nets (ditches and creeks). Means are shown with standard error.

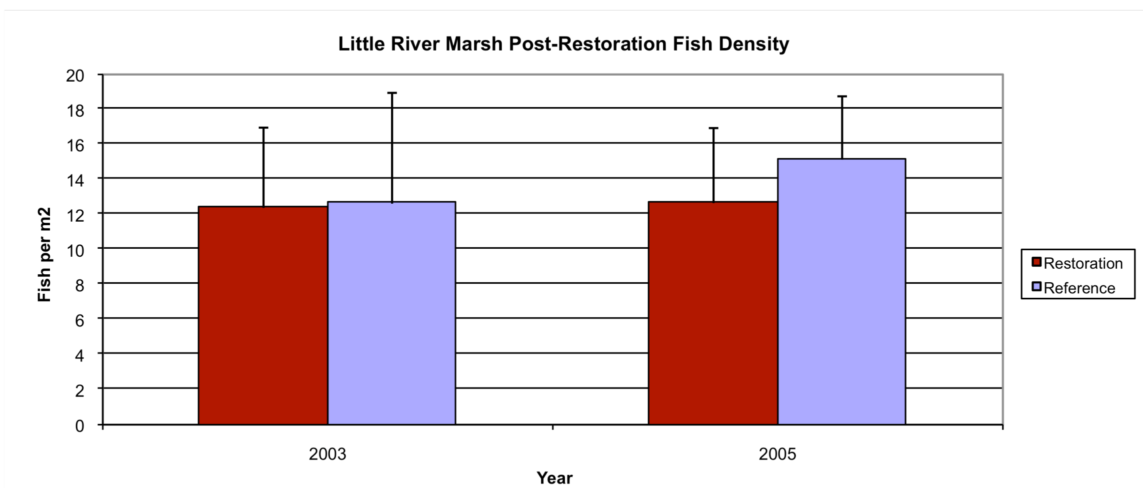


Figure 10. Post restoration nekton density for restoration and reference sites in 2003 and 2005. Means are shown with standard error.

Discussion

The goals of the restoration project at Little River were two-fold: 1) restore ecological function of the marsh by reestablishing regular tidal flooding; and 2) reduce the frequency and severity of local flooding to surrounding landowners. Our report evaluates progress toward the first goal using methods and protocols established for the region. Ecological restoration of marshes with restricted tides are typically assessed using four functional areas: hydrology, soils, vegetation and nekton (Neckles et al. 2002).

Installation of two large box culverts (each 1.8 by 3.6 m in cross-section) greatly enhanced tidal flow and freshwater drainage. Tidal records before restoration showed a muted signal (55 cm) and flooding associated with moderate rainfall (< 5 cm; Figure 4). After tidal restoration, we found a more natural hydrological regime with a spring tide range of 1.4 m. In addition, 78% of the potential tidal range occurred on the highest spring tides and 91% of the potential was measured on neap tides. Similar results were found in a regional study of tidal restoration in salt marshes (Konisky et al. 2006).

The chronic tidal restriction at Little River (Amman 1999) resulted in subsidence of the marsh surface so that tidal flooding following restoration regularly covered most of the marsh surface. This was not unexpected, since other researchers have found subsidence in restricted marshes (Portnoy and Giblin 1997, Anisfeld et al. 1999, Boumans et al. 2002, Williams and Orr 2002). Neap tides cover less than 20% of the reference marsh at Awcomin but over 50% of the marsh at Little River. We anticipate the regular tidal flooding will allow organic matter to accumulate, and over time increase the surface elevation of the marsh (Boumans et al. 2002). Another response to the greater tidal signal is the enlargement of tidal creeks through bank erosion and deepening, and results of both processes have been observed in Little River Marsh.

Soil salinity was depressed from the tidal restriction at Little River, as found at other restricted marshes (Roman et al. 1984, Portnoy and Giblin 1997, Burdick et al. 1997). Soil salinity increased over 50% (from 18 to 28 ppt) following restoration. Levels seemed to quickly stabilize within a narrow range that was similar to natural marsh conditions, as evidenced by comparison with the reference marsh.

One of the sentinels of marsh degradation is the establishment and expansion of exotic invasive species such as *Phragmites australis* and *Lythrum salicaria* (Roman et al. 1984, Burdick et al. 1997). Although *Phragmites australis* is certainly a native species, the variety found in degraded marshes along the Atlantic seaboard (and Little River Marsh) is an exotic variety from Eurasia (Saltonstall 2002). Both the exotic variety of

Phragmites and *Lythrum* were distributed widely in the marsh at Little River, along with salt intolerant shrubs like *Myrica gale* (sweet gale), *Rosa rugosa* (Salt-spray rose), and *Alnus rugosa* (speckled alder) (Burdick 2002). As part of the goal to restore ecological function, we hoped to reestablish natural vegetative communities native to salt marshes that were lost as a result of tidal restriction.

The increased volume and reach of tidal flows throughout the marsh, along with the resulting increase in salinity levels, led to slow but significant changes in vegetation composition and areal cover for halophytes and invasive exotics. *Lythrum*, which is more salt sensitive than *Phragmites*, disappeared from all our vegetation plots and only three plots supported *Phragmites* by 2005. By 2005, species of concern had declined significantly with respect to percentage plant cover (from over 8% to under 1% cover). Dramatic losses of *Lythrum* contrasted with little change in *Phragmites* has been observed at other sites (Burdick et al. 1999), so it is satisfying to observe declines in *Phragmites* at Little River. Broad areas of the marsh should be too stressful with respect to salinity (averaging > 20 ppt) for long-term survival of the exotic variety of *Phragmites* according to recent greenhouse experiments (Vasquez et al. 2005). There are some large stands of *Phragmites* remaining in the marsh and it will be interesting to see if they continue to contract or migrate to fresher portions of the marsh.

A shift in areal cover dominance from bare ground, open water, and dead vegetation to halophytic vegetation occurred slowly and did not become statistically significant until five years after the hydrologic enhancement. The shift in dominance from the "Other" category to halophytic vegetation after five years likely reflects the die-back of brackish and freshwater wetland vegetation that had invaded the area during times of habitat fragmentation and tidal restriction, and the re-establishment of salt tolerant species in response to enhanced tidal flooding cycles.

Success in expanding nekton habitat at Little River was evidenced by post restoration nekton densities equal to densities sampled before restoration and equal to densities sampled in the reference area. Only severely restricted tides prevent small fish and crustaceans from populating creeks and pools of degrading marshes (Raposa and Roman 2003). Although the density of fish within pools and creeks may not have increased after restoration, the increases in flooding and flooded habitat likely represent an important benefit to fish and wildlife. In addition, replacement of *Phragmites* by native vegetation will benefit mummichogs (Able 2002, Able et al. 2003).

Tides now flood the marsh surface every day, providing important foraging habitat and access to new areas by connecting pools and pannes to tidal creeks. Small fish such as mummichogs help to control mosquito populations by preying on larvae in pannes and pools. Nekton and mummichogs in particular, are an important link in the flow of energy transfer through the marsh to areas beyond the estuarine system (i.e., avian and mammalian predators; and as prey supporting off-shore fisheries). The large culverts are now likely to support fish passage to and from the marsh.

Not every portion of the marsh has experienced desirable outcomes, however. A stand of red maple (*Acer rubum*) trees at the northwest corner of the marsh were flooded and killed by salinity. A fresh shrub swamp in the southwest corner also was killed as it slowly reverts to a brackish system. Mosquitoes bred in the cradles of the toppled maples as well as in areas subject to flooding that have poor drainage, leading to a mosquito problem for area residents (Reilly et al. 2006). As an adaptive human response to the mosquito problem, a smaller restoration project has just begun in the western portion. Tidal channels will be excavated to enhance fish access (and thereby increase predation on mosquito larvae) and the dead brush will be removed to aid human access for mosquito control.

In summary, Little River Marsh shows a clear trajectory towards establishment of a functioning salt marsh system. In the year following installation of the culverts, soil salinity increased and became similar to levels found at Awcomin Marsh. Steady change in vegetation cover and decline of invasive plants at Little River led to similar cover of broad plant groups when compared to Awcomin Marsh in 2005. However, the Little River Marsh restoration area is still in a state of dynamic change and more time is required for the full range of ecological functions and values to become realized at this site.

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Appendices

Appendix 1. Example of Hydrology Data

Tidal Signal		
	Little River	Awcomin
Date & Time	**Restoration**	**Reference**
	NGVD (m)	NGVD (m)
10/25/06 0:09	0.120434879	-0.320378663
10/25/06 0:19	0.120434879	-0.320378663
10/25/06 0:29	0.120434879	-0.320378663
10/25/06 0:39	0.120434879	-0.320378663
10/25/06 0:49	0.120434879	-0.320378663
10/25/06 0:59	0.120434879	-0.320378663
10/25/06 1:09	0.120434879	-0.320378663
10/25/06 1:19	0.120434879	-0.320378663
10/25/06 1:29	0.120434879	-0.320378663
10/25/06 1:39	0.120434879	-0.320378663
10/25/06 1:49	0.120434879	-0.320378663
10/25/06 1:59	0.120434879	-0.320378663
10/25/06 2:09	0.120434879	-0.320378663
10/25/06 2:19	0.120434879	-0.320378663
10/25/06 2:29	0.120434879	-0.320378663
10/25/06 2:39	0.120434879	-0.320378663
10/25/06 2:49	0.120434879	-0.320378663
10/25/06 2:59	0.120434879	-0.320378663
10/25/06 3:09	0.120434879	-0.320378663
10/25/06 3:19	0.120434879	-0.320378663
10/25/06 3:29	0.120434879	-0.320378663
10/25/06 3:39	0.120434879	-0.320378663
10/25/06 3:49	0.120434879	-0.320378663
10/25/06 3:59	0.120434879	-0.320378663
10/25/06 4:09	0.120434879	-0.320378663
10/25/06 4:19	0.120434879	-0.320378663

Hypsometric Data				
Little River Restoration			**Awcomin Reference**	
Elevation NGVD (m)	Area above elevation		Elevation NGVD (m)	Area above elevation
-0.6193096	0		-1.1753088	0
-0.4493096	0.917		-0.4503504	0.885
-0.2693096	1.835		-0.4153504	1.77
-0.2393096	2.752		0.0646496	2.655
0.2506904	3.67		0.4646496	3.54
0.3106904	4.587		0.9096496	4.425

Appendix 2. Example of Salinity Data

Site	Year	Treatment	Station	Mean
Little River	1999	Pre	S1	33.00
Little River	1999	Pre	S2	32.00
Little River	1999	Pre	S3	13.00
Little River	1999	Pre	S4	27.00
Little River	1999	Pre	S5	25.00
Little River	1999	Pre	S6	33.00
Little River	1999	Pre	S7	29.00
Little River	1999	Pre	S8	13.00
Little River	1999	Pre	S1	34.00
Little River	1999	Pre	S2	15.00
Little River	1999	Pre	S3	32.00
Little River	1999	Pre	S4	25.00
Little River	1999	Pre	S5	25.00
Little River	1999	Pre	S6	35.00
Little River	1999	Pre	S7	25.00
Little River	1999	Pre	S8	
Little River	1999	Pre	S1	20.00
Little River	1999	Pre	S2	9.00
Little River	1999	Pre	S3	12.00
Little River	1999	Pre	S4	19.00
Little River	1999	Pre	S5	19.00
Little River	1999	Pre	S6	3.00
Little River	1999	Pre	S7	5.00
Little River	1999	Pre	S8	9.00
Little River	1999	Pre	S1	25.00
Little River	1999	Pre	S2	14.00
Little River	1999	Pre	S3	8.00
Little River	1999	Pre	S4	15.00
Little River	1999	Pre	S5	12.00
Little River	1999	Pre	S6	15.00
Little River	1999	Pre	S7	8.00
Little River	1999	Pre	S8	10.00
Little River	2000	Pre	S1	27.00
Little River	2000	Pre	S2	24.00
Little River	2000	Pre	S3	
Little River	2000	Pre	S4	2.00
Little River	2000	Pre	S5	13.00
Little River	2000	Pre	S6	5.00
Little River	2000	Pre	S7	
Little River	2000	Pre	S8	
Little River	2000	Pre	S1	20.00
Little River	2000	Pre	S2	24.00
Little River	2000	Pre	S3	12.00
Little River	2000	Pre	S4	4.00
Little River	2000	Pre	S5	20.00
Little River	2000	Pre	S6	9.00
Little River	2000	Pre	S7	16.00
Little River	2000	Pre	S8	6.00
Little River	2000	Pre	S1	20.00
Little River	2000	Pre	S2	20.00

Appendix 3. Example of Vegetation Data

Site	Year	Time	Treatment	Transect #	Halophytic Cover	Brackish Cover	Species of Concern	Total Live Cover	Dead Cover	Unvegetated /Bare Mud	Open Water Cover	Algae	Wrack	Other
Little River	2001	Pre	Res	1	40	50	50	90	0	10	0	0	0	10
Little River	2001	Pre	Res	1	65	10	10	75	0	25	0	0	0	25
Little River	2001	Pre	Res	1	9	1	1	10	0	90	0	0	0	90
Little River	2001	Pre	Res	1	16	50	50	66	0	34	0	0	0	34
Little River	2001	Pre	Res	1	10	5	0	15	0	85	0	0	0	85
Little River	2001	Pre	Res	2	90	0	0	90	0	10	0	0	0	10
Little River	2001	Pre	Res	2	95	0	0	95	0	5	0	0	0	5
Little River	2001	Pre	Res	2	15	0	0	15	0	85	0	0	0	85
Little River	2001	Pre	Res	2	1	0	0	1	0	99	0	0	0	99
Little River	2001	Pre	Res	2	0	0	0	0	0	40	50	10	0	100
Little River	2001	Pre	Res	2	55	0	0	55	0	45	0	0	0	45
Little River	2001	Pre	Res	2	75	0	0	75	0	5	20	0	0	25
Little River	2001	Pre	Res	2	55	0	0	55	0	45	0	0	0	45
Little River	2001	Pre	Res	2	0	2	2	2	0	98	0	0	0	98
Little River	2001	Pre	Res	3E	70	0	0	70	0	30	0	0	0	30
Little River	2001	Pre	Res	3E	65	0	0	65	0	35	0	0	0	35
Little River	2001	Pre	Res	3E	65	0	0	65	0	35	0	0	0	35
Little River	2001	Pre	Res	3E	65	0	0	65	0	35	0	0	0	35
Little River	2001	Pre	Res	3E	50	0	0	50	0	50	0	0	0	50
Little River	2001	Pre	Res	3E	50	0	0	50	10	40	0	0	0	40
Little River	2001	Pre	Res	3E	85	0	0	85	0	15	0	0	0	15
Little River	2001	Pre	Res	3E	60	0	0	60	0	0	40	0	0	40
Little River	2001	Pre	Res	3E	52	0	0	52	26	22	0	0	0	22
Little River	2001	Pre	Res	3E	46	5	5	51	0	49	0	0	0	49

Appendix 4. Nekton Data

Site	Station	Year	Habitat	Mgnt Type	Fish per m2	# Species	Fish per m3	Total Nekton per m2	Water Temp (C)	Salinity (ppt)	DO (mg/L)	DO (% Sat)
Little River	15	2000	Pool	Res	12							
Little River	16	2000	Pool	Res	5							
Little River	17	2000	Channel	Res	0							
Little River	18	2000	Channel	Res	34							
Little River	D1	2003	Channel	Res	43.37	2	309.76	43.37	22.1	22.6	1.80	21.8
Little River	D2	2003	Channel	Res	4.39	1	17.55	4.39	18.8	27.2	1.64	20.7
Little River	D3	2003	Channel	Res	0.95	1	4.75	0.95	25.8	15.9	6.80	92.3
Little River	D4	2003	Channel	Res	0.00	0	0.00	0.00	19.7	7.8	3.18	36.2
Little River	D5	2003	Channel	Res	15.11	2	50.36	18.59	18.4	25.6	5.53	69.6
Little River	D6	2003	Channel	Res	14.06	3	51.11	15.46	21.6	20.4	4.16	51.5
Little River	D7	2003	Channel	Res	0.00	0	0.00	0.00	21.5	24.7	0.60	8.1
Little River	P2	2003	Pool	Res	5.93	2	0.00	5.93	28.5	28.0	8.81	133
Little River	P3	2003	Pool	Res	1.01	1	6.52	1.01	30.5	25.0	1.40	15
Little River	P4	2003	Pool	Res	66.67	2	444.44	66.67	30.3	21.3	10.25	151.2
Little River	P5	2003	Pool	Res	13.10	2	48.53	13.10	27.5	28.0	6.20	91.6
Little River	P6	2003	Pool	Res	1.56	1	5.38	1.56	22.5	30.3	4.70	0.37
Little River	P7	2003	Pool	Res	0.00	0	0.00	0.00	24.4	22.3	6.74	89.7
Little River	P8	2003	Pool	Res	0.00	0	0.00	0.00	28.3	18.2	5.29	71.8
Little River	P9	2003	Pool	Res	16.84	2	70.15	16.84	27.5	27.0	3.42	50.2
Little River	P10	2003	Pool	Res	15.09	1	53.88	15.09	33.0	22.0	16.70	260
Little River	D1	2005	Channel	Res	0.00	0.00	0.00	0.00	16.80	29.70	9.17	112.60
Little River	D2	2005	Channel	Res	0.00	0.00	0.00	0.00	21.50	29.70	8.50	115.70
Little River	D3	2005	Channel	Res	0.00	0.00	0.00	0.00	21.30	29.40	7.18	98.10
Little River	D4	2005	Channel	Res	2.62	1.00	18.80	2.62	22.30	29.30	6.68	93.50
Little River	D5	2005	Channel	Res	0.00	1.00	0.00	1.93	19.40	29.80	80.00	6.11
Little River	D6	2005	Channel	Res	0.00	0.00	0.00	0.00	16.90	29.40	8.69	107.00
Little River	D7	2005	Channel	Res	0.00	1.00	0.00	1.16	16.10	29.30	9.33	115.00
Little River	D8	2005	Channel	Res	12.09	3.00	42.78	13.82	25.30	28.60	2.52	36.50
Little River	D9	2005	Channel	Res	177.57	2.00	461.98	177.57	26.20	30.30	2.64	38.60
Little River	D10	2005	Channel	Res								
Little River	P1	2005	Pool	Res	20.92	2.00	209.22	21.64	26.90	30.00	7.78	121.20

Little River	P2	2005	Pool	Res	28.16	1.00	160.90	28.16	27.80	31.60	4.23	62.40
Little River	P3	2005	Pool	Res	11.52	2.00	38.41	11.52	26.30	30.60	1.12	62.60
Little River	P4	2005	Pool	Res	73.75	1.00	670.48	73.75	29.20	30.60	13.80	203.10
Little River	P5	2005	Pool	Res	26.88	1.00	168.01	26.88	27.40	31.10	8.19	94.00
Little River	P6	2005	Pool	Res	14.98	2.00	44.72	15.61	25.80	30.50	13.50	200.00
Little River	P7	2005	Pool	Res	8.24	1.00	40.17	8.24	29.60	31.20	10.20	159.20
Little River	P8	2005	Pool	Res	0.00	0.00	0.00	0.00	29.60	31.20	6.73	105.70
Little River	P9	2005	Pool	Res	22.12	1.00	245.73	22.12	33.40	32.70	5.26	87.90
Little River	P10	2005	Pool	Res	6.43	1.00	18.91	6.43	31.50	32.50	4.86	81.40
Awcomin	D8	2003	Channel	Ref	19.66	3	26.04	23.40	19.10	5.13	68.20	22.47
Awcomin	D9	2003	Channel	Ref	18.21	2	63.89	26.50	17.10	7.56	98.60	18.21
Awcomin	D10	2003	Channel	Ref	0.00	0	0.00	26.20	1.60	6.79	85.20	0.00
Awcomin	D8	2005	Channel	Ref	6.62	2.00	12.04	24.80	25.00	8.67	112.00	7.94
Awcomin	D9	2005	Channel	Ref	1.04	1.00	1.86	26.10	24.30	8.00	114.00	1.04
Awcomin	D10	2005	Channel	Ref	13.78	3.00	20.57	25.70	26.30	8.60	121.00	13.78
Awcomin	D11	2005	Channel	Ref	1.00	2.00	1.11	26.00	28.80	7.50	110.00	2.99
Awcomin	P11	2005	Pool	Ref	29.12	1.00	171.29	31.00	28.00	6.80	100.00	29.12
Awcomin	P12	2005	Pool	Ref	13.13	1.00	52.51	31.10	29.30	9.02	143.00	13.13
Awcomin	P13	2005	Pool	Ref	5.38	2.00	26.91	30.80	30.00	9.02	136.00	5.38
Awcomin	P14	2005	Pool	Ref	20.60	2.00	89.56	31.90	29.60	160.00	10.04	20.60
Awcomin	P15	2005	Pool	Ref	15.13	2.00	58.18	32.00	29.20	11.58	181.00	15.13
Awcomin	P16	2005	Pool	Ref	39.71	1.00	132.38	31.20	28.50	16.20	160.00	39.71
Awcomin	P17	2005	Pool	Ref	21.01	4.00	84.02	31.20	29.70	8.35	132.00	21.59