

Anadromous and Resident Fish Distributions and Trophic Web Structure in Merrymeeting Bay, Maine.

The Doherty Coastal Studies Research Fellowship
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Atlantic Sturgeon - *Acipenser oxyrinchus*
averages 6-10 feet



Introduction

The Merrymeeting Bay ecosystem and human settlements around it have long been ecologically and economically intertwined, specifically regarding the anadromous fish that utilize the ecosystem as a nursery habitat. Before European settlement, Native Americans utilized the enormous populations of *Salmo salar* (Atlantic Salmon), *Alosa pseudoharengus* (Alewife), *Clupea harengus* (Atlantic Herring), *Alosa sapidissima* (American Shad), *Morone saxatilis* (Striped Bass) and *Acipenser brevirostrum* (Short-nosed Sturgeon) migrating from the ocean as an important seasonal protein source. In the 1600s, European settlers founded commercial fisheries utilizing the abundance of anadromous fish. This marked the beginning of a human disturbance regime that profoundly affected the Merrymeeting Bay ecosystem. Deforestation in the area surrounding the bay led to increased rates of sedimentation, affecting the substrate composition of the Bay and causing it to become permanently shallower. During the Industrial period, mills and factories sprang up along the banks of the bay's tributaries, releasing untreated waste into the rivers. The input of pollution containing a high amount of organic matter resulted in eutrophication events, causing almost chronic anoxia due to increased microbiological respiration, as well as numerous algal blooms and fish kills. (Lichter et al., 2006) Simultaneous with this pollution, the population collapse had wide-ranging ecological impacts. Studies indicate that in many ecosystems, anadromous fish function as the keystone species, as they provide an important food source for terrestrial piscivores, including *Haliaeetus leucocephalus* (Bald Eagle) and *Pandion haliaetus* (Osprey). (Willson and Halupka, 1994) A study by Mark Burton ('07) suggests the intensity and duration of this disturbance regime caused a shift in the stable state of Merrymeeting Bay, transforming it from a clear-water, vegetated ecosystem to one characterized by turbidity and degraded water quality. This stable state caused a decline in beds of Submerged Aquatic Vegetation (SAV) in the bay, due to pollution and decreased light penetration. (Burton, 2007)

Beds of SAV are extremely ecologically important to the Merrymeeting Bay ecosystem. Studies on systems similar to Merrymeeting Bay have indicated that the density and biodiversity of fish are both greater in vegetated habitats compared to unvegetated areas. (Orth and Heck, 1980) SAV beds provide habitat for microinvertebrates as well as the juvenile resident and anadromous fish that prey on them. Also, fish use beds of SAV for predator avoidance.

There are many positive feedback cycles associated with the loss of SAV, perpetuating a turbid stable state. SAV causes suspended solids to settle to the bottom, and their substantial root system traps sediments on the substrate. Our study was an investigation of the feasibility of a large-scale transplant of SAV into the bay and determines the ecological impacts. This project focused specifically on the behavior of resident and anadromous fish in relation to transplants of Submerged Aquatic Vegetation. Based on previous studies, I hypothesize that both resident fish and anadromous juveniles will benefit from the transplants of Submerged Aquatic Vegetation.

Methods

Site Description

Merrymeeting Bay is a freshwater, tidal ecosystem located approximately 30 kilometers inland from Maine's midcoast. It is formed by the confluence of six rivers, the Kennebec, Androscoggin, Eastern, Muddy, Cathance, and the Abbagadasset. The Kennebec and the Androscoggin rivers are the second and third largest rivers in Maine, respectively. Thus, approximately one-third of the area of Maine drains into Merrymeeting Bay. High levels of nutrients drain into the bay from its tributary rivers, making it an unusually productive ecosystem. Merrymeeting Bay is well mixed and very shallow, with expansive mudflats exposed at low tide. Wild rice covers these mud flats, providing an ideal forage habitat for ducks and other waterfowl. The ecosystem has historically supported an abundance of other biodiversity, but centuries of intense disturbance have left it severely altered. Since the ratification of the Clean Water Act in 1972, there is evidence of some recovery, though Merrymeeting Bay remains a degraded ecosystem.

Transplant

Four sites were chosen across the bay and at each site two meter square plots were marked with wooden stakes, one of which was densely vegetated, the other devoid of SAV. Thirty *Vallisneria americana* (Tape grass) were planted in each plot in early June, and their mortality was monitored through the month of July.

Fish Survey

At each plot, standard minnow traps were suspended from stakes approximately 10 cm above the substrate. Stakes were placed just inside the edge of the plot and traps were oriented with the predominate flow of the tide. An addition trap was placed on a submerged sandbar, onto which no vegetation was transplanted and no vegetation was present within 5 meters of the minnow trap. Number of fish caught per day in the trap was measured as Catch per Unit Effort (CPUE).

Water and Substrate Analysis

Chlorophyll, pH, Turbidity, and temperature were measured three to five times a week using a Sonde 6600 (YSI corporation). Substrate particle size was determined by sieving sediment samples collected with a Plexiglas corer. Only the top 10 cm of the substrate were sampled. Percent organic by weight was determined by placing samples in a muffle furnace at 500°C for a minimum of four hours.

Statistical Analysis

Statistical analysis was performed using SPSS version 12.1.4 for Windows.

Results

No significant difference was found between the Catch per Unit Effort during the entire study period in the previously vegetated and the previously unvegetated plots (P=0.307), figure 1. However, this was not consistent throughout the study period. Before the median date of the study period (July 1, 2008), the previously unvegetated plots had a significantly lower CPUE than the previously vegetated plots (P=0.002). After the median date, data gathered indicate that there was no significant difference between the previously vegetated and unvegetated plots (P=0.652).

Also, data gathered during the entirety of the study show that a significantly higher CPUE was observed in the previously vegetated plots than the Sand Bar plot (P=0.029), whereas no significant difference in the CPUE was found between the previously unvegetated plots and the Sand Bar control site (P=0.187), see figure 4.

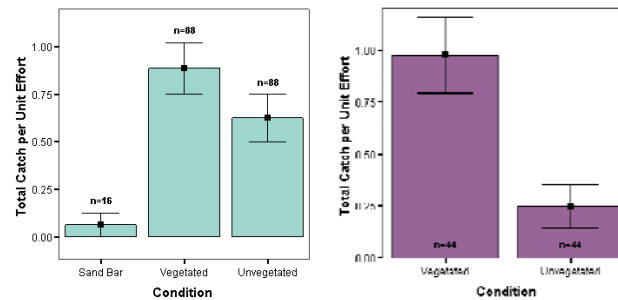


Figure 1. Total Catch per Unit Effort for the Previously Vegetated and Previously Unvegetated plots from all sites and the Sand Bar site. The previously vegetated site yielded a significantly higher CPUE than both the Sand Bar site and the unvegetated plots (P=0.029). However, there was no significant difference between the previously vegetated and unvegetated plots (P=0.307) and the unvegetated plots and Sand Bar control site (P=0.187). Error bars represent standard error of the mean.

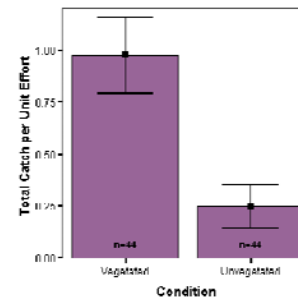


Figure 2. Total Catch per Unit Effort for the Previously Vegetated and Previously Unvegetated plots from all study sites before July 1, 2008. Unvegetated plots yielded significantly less CPUE than the Vegetated plots (P=0.002). Error bars represent standard error of the mean.

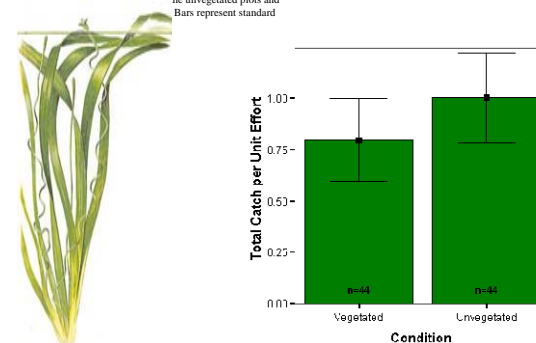


Figure 3. Total Catch per Unit Effort for the Previously Vegetated and Previously Unvegetated plots from all study sites after July 1, 2008. No significant difference was observed between the vegetated and unvegetated plots (P=0.652). Error bars represent standard error of the mean.

Tapegrass, *Vallisneria americana*



Alewife, *Alosa pseudoharengus*

Discussion

The results from this study both support and cast doubt on my initial hypothesis. Based on previous studies on the relationship between resident and anadromous fish and Submerged Aquatic Vegetation, I postulated that plots of SAV provide an important microhabitat for both varieties of fish, and thus the previously vegetated plots would yield higher CPUEs than previously unvegetated plots, due to higher vegetation densities (Orth and Heck, 1980). However, I also hypothesized that all transplanted plots would yield greater CPUEs than the completely unvegetated Sand Bar site. Essentially, both categories of fish would benefit from a large-scale transplant of Submerged Aquatic vegetation into Merrymeeting Bay.

The data show that, initially, the data from the previously unvegetated plots did not indicate that the transplant was being utilized by resident and anadromous juvenile fish and there was little evidence that the transplanted plots were serving as foraging and predator avoidance areas (figure 2). But after the median date of the study period, approximately one month after the transplant, the data indicate that the previously unvegetated plots were utilized to the same extent as the previously vegetated plots (figure 3).

A probable cause of these observations is transplant shock. When plants are transferred into a new environment, there is considerable dieback in the leaves, and some mortality. This effectively reduces the density of the vegetation of the plot and thus makes it a less ideal habitat for resident and juvenile anadromous fish. Perhaps after the transplanted plots were able to recover from the shock of transplant (i.e. after July 1, 2008), the density within the plots became sufficient enough to support some upper trophic level organisms.

However, when data gathered throughout the summer at the previously unvegetated and the completely unvegetated Sand Bar plot were compared, no significant difference was found. This indicates that it is also possible transplants were not utilized by the resident and juvenile anadromous fish (figure 4).

The data gathered in this study provides an excellent direction in which to proceed with the restoration of Merrymeeting Bay. The aggregated human disturbance of centuries of overfishing, pollution and dam building have caused a shift in the stable state of the Merrymeeting Bay ecosystem from a benthic-based to pelagic based ecosystem, characterized by high turbidity levels and low oxygen concentrations. This shift had a negative impact on SAV beds and fish populations. By artificially recolonizing the Bay with SAV, it may be possible to cause a shift back to the original stable state, and restoring the historically high productivity levels. However, there is doubt as to whether transplanted SAV can provide a suitable microhabitat for resident and juvenile anadromous fish. There was no significant difference between the CPUE at the Sand Bar site and combined average CPUE of the previously unvegetated sites, indicating that it is also possible that transplanted SAV are not utilized. Thus, more studies are needed to determine whether a large-scale recolonization of the bay will benefit the bay and if it is worth the considerable economic investment. It will be important to observe the regrowth of the transplanted SAV following this winter, and verify that the plants are able to survive the winter. Also, controlled studies that investigate the changes in water quality parameters and fish behavior associated with different densities of SAV would further inform restoration efforts.

Literature Cited

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