Effects of Haul Seining on Submerged Aquatic Vegetation in Upper Chesapeake Bay

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Executive Summary

A bill was introduced in the 1996 session of the General Assembly to ban haul seining in the Susquehanna Flats prompted by a concern for the impact of haul seining on submerged aquatic vegetation (SAV). The House Environmental Matters Committee tabled the bill citing a lack of scientific information upon which to make a decision. In 1996, Maryland's Department of Natural Resources investigated the haul seine fishery's effect on SAV. Commercial haul seining had no detectable impact on the quantity or composition of submerged aquatic vegetation on the Susquehanna Flats in 1996. Test seining at three experimental sites of varying plant densities and species composition had no detectable effects on plant height, plant density or species composition. Video tapes taken during actual commercial haul seining and during test seining revealed that both commercial and DNR test seines easily rode over stands of SAV of varying density with little or no effect. Inspection of aerial photographs taken before and after commercial haul seining also revealed no discernable effect.

Two commercial haul seine crews filled their quota within eleven days from a total of 21 hauls in the northern portion of the Susquehanna Flats. The total area swept by the 21 hauls encompassed less than 2% of the total SAV acreage of the Susquehanna Flats.

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Acknowledgments

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Introduction

Submerged aquatic vegetation is a significant component of healthy estuarine ecosystems (Batiuk et al. 1992) and provides food and shelter for fish, shellfish and waterfowl. They positively influence nutrient cycling, water clarity and stability of shorelines and sediments (McRoy and Helfferich 1977, Phillips and McRoy 1980).

Over the past five years, the Susquehanna Flats at the Northern tip of Chesapeake Bay, has consistently supported the largest SAV beds in the Chesapeake Bay north of the Bay Bridge (Orth et al. 1995; Figure 1). The Flats cover approximately 88 km^2 (55 miles^2) and has an average depth at mean low tide of 1.2 m (4 ft). It is tidal freshwater with occasional late summer incursions of slightly salty water and the bottom is primarily silty-mud.

Sediment core samples from Furnace Bay, a shallow embayment on the northern side of the Susquehanna Flats, revealed seeds from an abundant and diverse population of SAV prior to European settlement (Brush and Davis 1984). Five species occurred continuously, including wild celery *(Vallisneria americana)*, elodea (*Elodea canadensis)*, slender naiad (*Najas gracillima)*, southern naiad *(Najas guadalupensis)* and northern naiad (*Najas flexilis)*. In 1930, Eurasian milfoil *(Myriophyllum spicatum)*, an exotic species, appeared and quickly became the dominant species in the Susquehanna Flats. Eurasian milfoil began to decline in 1958. After 1972, all SAV disappeared from the seed record, probably due to chronic (increased urbanization and poor agricultural practices), acute (Hurricane Agnes) sediment and nutrient loading and herbicides (Brush and Davis

1984, CRC 1976).

Combined aerial and ground surveys have monitored status and trends of SAV in Chesapeake Bay since 1984 (Orth et al. 1995). These surveys, conducted by Virginia Institute of Marine Science (VIMS) and numerous collaborators, give an overview of species diversity and variation in SAV beds during the past decade. Aquatic vegetation surveys of the Susquehanna Flats have found up to eight species, with Eurasian milfoil and hydrilla appearing most frequently (Orth et al. 1995). Acreage of SAV in Susquehanna Flats increased 58% between 1991 and 1994, although 87% of the beds were considered very sparse (Orth et al. 1995).

A haul seine is an active fishing system that traps fish by encircling them with a long fence-like wall of webbing (Hayes 1983). It is made of strong netting hung from a float line on the surface and held near the bottom by a lead line. By law, haul seines may be no more than 549 m (1,800 ft) long and 6.7 m (22 ft) deep in Chesapeake Bay. They are fished either along the shoreline where they are deployed in a semicircle to trap fish between shore and net or, more typically, fish are encircled away from shore, worked into an ever smaller pocket of net and lifted onto a boat for culling.

Haul seines have been fished in the Chesapeake Bay and tributaries since colonial days and captured many different species (Mansuetti and Kolb 1953; Walburg and Nichols 1967; Uphoff and Piavis 1993). Striped bass have been the primary species targeted by upper Chesapeake Bay haul seiners in recent years. For the past five years, striped bass haul seine landings from the Flats accounted for less than 2% of all commercially caught striped bass in Chesapeake Bay and less than 0.2% of Maryland finfish landings (all gears combined). The 1996 haul seine season in the Susquehanna Flats was set by regulation to run from late August through November.

Some citizens became concerned that commercial haul seining on the Susquehanna Flats was destroying SAV and eliminating its beneficial effects. During 1996, Maryland's Department of Natural Resources (DNR) investigated the extent commercial haul seines were used on the Susquehanna Flats and estimated the effect commercial haul seining had on SAV. We developed this study with input from major groups of stakeholders (recreational fishers, concerned citizens, environmentalists, commercial fishers and the Maryland Legislature) interested in the Susquehanna Flats. We estimated this effect by;

- assessing SAV species composition, density and height before and after experimental haul seining;
- observing commercial haul seining; and
- aerial photographic interpretation of commercial seining effects in SAV beds.

Methods

Experimental Seining

Three experimental haul seine sites were selected based on shoreline access, viable SAV communities and unobstructed seining areas: Oakington Cove, Stump Point and Havre de Grace Outfall (Figure 1). Each site consisted of a control and three treatment segments, T-1, T-2 and T-3. Controls were never seined but were sampled monthly for SAV (Table 1). A unique segment at each site was seined and sampled for SAV each month during July-September. To determine long term impacts, the segment initially seined and sampled in July was re-sampled in August and September. The segment seined and sampled in August was re-seined and re-sampled in September. As an additional test, a single haul was made at Oakington Cove in September to test impacts of additional lead line weights.

Nondestructive line-intercept quadrat sampling was used to sample SAV communities (Heidelbaugh and Nelson 1996; Titus 1993) at experimental sites. Two 31 m (100 ft) transect lines were randomly located perpendicular to shore at each treatment segment and ten randomly placed 0.25 or 1 m^2 quadrats were sampled along each transect. Presence or absence of SAV, number of plants, tallest plant and species richness were measured within each quadrat (Naylor and Kazyak 1995; American Public Health Association 1989; Pine et al. 1989). Each stem rising from the sediment was considered a plant, regardless of rhizome attachment (Sheldon and Boylen 1978). Sampling was conducted before and after seining. At least ten quadrats per segment were sampled for long-term effects.

For each experimental haul seine, we recorded start and end time, fish species caught and species and volume of SAV brought in with the seine. Volume of SAV was estimated by collecting and measuring SAV from a 3 m (10 ft) section of the seine and multiplying that volume by ten to extrapolate to the entire seine.

We obtained a portion of a commercial haul seine from watermen that fish the Susquehanna Flats and shortened it to a manageable length. The shortened haul seine was 31 m (102 ft) long, 3.1 m (10 ft) wide and had 50-43g (1.5 oz) lead weights attached to the bottom (lead) line. The top line had 44 evenly-spaced corks attached at 53 cm (1.75 ft) intervals. The seine was constructed of number 18 twine with an 8.9 cm (3.5 inches) stretch-mesh size.

We set the haul seine in our experiments by stationing one end just offshore and then pulling the other end out perpendicular to shore. After the net was fully extended, it was pivoted parallel to the shore, the distal end brought to the shore and both ends were pulled in by hand. The persons pulling the net placed a foot on the lead line to keep it in contact with the bottom. Twenty-five foot buffers were established on both sides of seined segments to prevent overlapping of treatments. Each SAV sampled quadrat was swept by the seine. Stump Point and Havre de Grace Outfall sites were seined at low tide because they were too deep at high tide, while the shallower Cove site could be sampled regardless of tidal state.

We used mixed effects analysis of variance (ANOVA) models to test null hypotheses that variability in density or plant height were the same regardless of treatment (before and after seining or never seined; fixed effect), month (July, August, or September; fixed effect) or site (Cove, Outfall or Stump Point; random effect; Sokal and Rohlf 1981; Dowdy and Weardon 1991; Littell et al. 1991). Density and height data were normalized by $\log_e$-transformation. One was added to density to eliminate zeros, but not to height. Density was determined by dividing plant count by the area of the quadrat used (0.25 m^2 or 1.0 m^2). The probability of a Type I error (probability of rejecting a true null hypothesis) was 0.05 or less ($\propto \leq 0.05$). Alternative hypotheses were that significant variability existed due to treatment effects.

The ANOVA models looked at immediate and long-term effects of seining. Immediate effects were investigated by testing treatments (before, after, or never seined) only for the month (July, August or September) they were seined. Long-term effects were tested with two ANOVA models of the initial month (July or August) of treatment (after or never seined) and follow up visits. Treatments seined in July were sampled again in August and September (hereafter the + two month ANOVA) and treatments seined in August were sampled again in September (hereafter the + one month ANOVA).

We were primarily interested in tests and estimates related to treatment. Variation among months and sites had to be accounted for to determine treatment differences. Each ANOVA modeled month, site, treatment, interaction of treatment and site and interaction of month, site and treatment. In this analysis, the F test for significant differences among treatments required the mean square for the interaction of month, site and treatment be used in the denominator (Dowdy and Weardon 1991). A reduced model was formulated if any main effect other than treatment was not significant at $P \leq 0.05$ and the mean square of the remaining interaction was used as the denominator of the F test. Residuals of each ANOVA were examined for normality (Dowdy and Weardon 1991).

The concept of statistical power (one minus the probability of Type II error or $1 - \beta$) was applied to interpret ANOVA models where the hypothesis that all treatments were equal was not rejected (Peterman 1990). Power reflects the probability of correctly not rejecting the hypothesis that all treatments were the same. Power is a function of the level of significance, effect size (f, a function of differences in means), sample size and variance. Knowledge of power is useful when management actions may be recommended on the basis of no difference (Peterman 1990). We calculated power using Cohen's (1977) power tables and methodology for treatment (seining) as a main effect in a complex ANOVA design. The mean square of the denominator of the F test of the hypothesis was used as the standard deviation (Cohen 1977). Power was set at 0.95 to be as conservative about Type II error as Type I. When power fell below 0.95, reverse power analysis (Peterman 1989) was used to indicate effect size (f_{min}; Cohen 1977) where power equaled 0.95 and power at the anticipated effect size (f_a). An effect size up to 0.20 indicated a small effect, a large effect was indicated by f more than 0.50 and moderate f was between these values (Cohen 1977). Given stakeholder accounts of extensive destruction of SAV by haul seining, we set f_a at 0.50 when we designed the experiment.

We used a Kruskal-Wallis Test to evaluate the hypothesis that there were no differences in density rank distribution before and immediately after seining; the alternative hypothesis was that there were differences (Ott 1977). Months and sites were combined, but follow-up visits for July and August trials were excluded.

We determined the proportion of quadrats occupied by each species before and after seining for all months and sites combined. The normal distribution approximation of the binomial distribution was used to estimate 95% confidence intervals (95% CI) and differences in proportions were determined from their overlap (Ott 1977). These CI comparisons were only made when before and after proportions were significantly different from zero. Power was set at 0.95 to be as conservative about Type II error as Type I and was calculated with Cohen's (1977) power tables and methodology. When power fell below 0.95, reverse power analysis (Peterman 1989) determined f_{min} and f_{a}.

Log_e-transformed densities and tallest plant heights before and after pulling a seine with twice the amount of lead-line weights (1.5 ounces every foot) were compared with a t-test (Dowdy and Weardon 1991). These trials were conducted during September at Oakington Cove. Power was approximated using Cohen's (1977) power tables and methodology.

Commercial Haul Seine Observations

We accompanied commercial seiners on the Susquehanna Flats during the 1996 haul seine season. Only two haul seine crews fished this area and we obtained their permission to observe and collect data. Seines were set and fished at the discretion of the watermen to maximize their striped bass catch.

Observers collected the following data: time the seine was set and closed, Digital Global Positioning System (DGPS) location (using a Magellan NAV 5000 DLX with Magellan DRB differential), percentage of SAV in haul seines by species, estimated fish catch by species and SAV density category in the area seined. Plant density before and after seining was categorized as no plants, slight density (<10 SAV per m^2), moderate density (11-25 SAV per m^2) and heavy density (>25 SAV per m^2).

Commercial haul seines were 529 m long x 2.4 m tall (1,700 ft long x 8 ft tall; Figure 2) and 488 m long x 4.6 m tall (1,600 ft long x 15 ft tall; Figure 3). The cone-shaped pockets were similar in size, but differed in location. One was located in the middle of the net and the other was offset near the brail pole (a heavy wooden pole at the end of the seine used for stationing the net). Weights were evenly distributed on the lead line except the lead line in the mouth of both pockets had more weight (Appendix 1).

Commercial haul seines were loaded on small barges approximately 5.5 m (18 ft) long and towed by boat. Haul seines were set by driving the brail pole into the substrate and towing the barge in a circle to pull the seine off. An approximately 100-foot line from a gasoline powered winch on the barge was hooked to the seine and pulled to the barge, unhooked, attached again and repeated until approximately 75 m (250 ft) remained to be retrieved. Watermen then pulled the net by hand until fish were forced into the pocket. Finally, the net was lifted onto a boat and the catch was culled.

Pocket location caused seine retrieving to be unique to each crew. The crew working the seine with the center pocket pulled wings alternately, whereas the crew working the side pocket seine pulled one wing only. During winching and hand retrieving, one person physically held up the cork line to contain captured fish.

Aerial Photography

To evaluate damage to SAV by commercial and experimental haul seines, potential seine areas were to be photographed before seining started and after it concluded. Photography was done by the same company that regularly photographed for the bay-wide Virginia Institute of Marine Science (VIMS) survey. Photographs were interpreted by Robert Orth of VIMS, in accordance with protocols set out in Orth et al. (1995). Experimental haul seine sites were photographed at half the normal altitude to increase resolution.

Aerial photographs were scanned into a Geographical Information System (GIS) and referenced to satellite images using the photo center point and shoreline features. Submerged aquatic vegetation beds interpreted by R. Orth were scanned, digitized and DGPS readings recorded from commercial operations were overlaid upon this. The approximately four-acre area of a haul seine set was large enough to be viewed easily on an aerial photograph. Photographic interpretation of SAV beds before and after commercial seining were compared to see if SAV beds had been changed by commercial seining. If SAV damage occurred, patches of reduced density or SAV absence would appear within plant beds.

Results and Discussion

Experimental Seining

Haul seine experiments began on 9 July and concluded on 20 September, 1996 (Table 1). Considerable differences existed between sites, both physically and biologically. Water depth was greatest at Stump Point with an average depth of 97 cm (3.1 ft). The Outfall and Cove had average depths of 79 and 38 cm, respectively (2.6 and 1.2 ft). Plants at Stump Point were taller than those at Outfall or Cove. Height was consistent within each site throughout the study (Figure 4). Mean SAV densities at a given site ranged from 30 to 200 plants per m^2. Sites dominated by hydrilla increased in plant density from July to September, while sites dominated by wild celery decreased in density.

Plant communities differed between sites (Table 2). Stump Point was dominated by native wild celery, which was present in 82% of quadrats. Both the Cove and Outfall had exotic hydrilla present in 98% of sampled quadrats. Other species found at all sites included water stargrass *(Heteranthra dubia)*, naiads *(Najas* sp.), southern naiad, Eurasian milfoil and coontail *(Ceratophyllum demersum)*. Slender pondweed *(Potamogeton pusillus)* was found at the Outfall site only (Table 2).

There was no significant difference in the proportion of quadrats with a particular species of plant before and after seining; five species had proportions significantly different from zero ($P \leq 0.05$; Table 3). Power was low, less than 0.30, for all comparisons because of low f (≤ 0.10). At f_o, power exceeded 0.99 and f_{min} equaled 0.35.

Full ANOVA models of $\log_e$-transformed densities and tallest plant heights were significant ($P \leq 0.05$). Immediate impacts of seining on density (Table 4) and height (Table 5) were not significant. A reduced model was needed with the immediate effect on height, but again, seining did not have a significant impact (Table 6). Seining had no significant impact in either the + two month (Table 7) or + one month (Table 8) long-term ANOVA models of density or height (Tables 9 and 10, respectively). Significant differences in density class were not found before and immediately after haul seining (Kruskal-Wallis Test, Chi-square = 2.61, $P \leq 0.11$), confirming ANOVA results.

The ANOVA models indicated haul seining with normally weighted seines (1.5 ounce lead weight every two feet) did not reduce plant density or height. Power was sufficient to determine that all but a small impact was absent. Power was low (< 0.50) for all ANOVA models (density and height) of immediate or long-term effects because effect sizes were smaller (<0.01 to 0.12) than anticipated ($f_a = 0.50$; Table 11). Power to detect f_a was greater than 0.95 in all cases. Effective sample sizes of these experiments were sufficient for f_{min} to be less than 0.30. Means of $\log_e$-transformed plant densities (+1) and tallest plant heights by ANOVA model and treatment are presented in Appendix 2.

The Outfall had the highest captured SAV biomass in the experimental haul seine in September (336 liters), while Stump Point had the lowest biomass in September (1 liter). A bluegill and a carp were the only fishes caught in the experimental seine. There was no reduction in SAV density in seined transects and the SAV captured in the experimental seine is loose in the seined area and has been broken off or dislodged by other means and captured by the seine. Windrows of broken SAV were often present at the high water mark on experimental beaches. The source of this SAV was probably wave action from boats and wind, rooting activity by carp and natural die-off of stems.

In a separate test to determine the effects of a double weighted haul seine, mean $\log_e$-transformed plant density ($t = -1.59$, $P \leq 0.13$, $N = 18$) and heights ($t = 0.59$, $P \leq 0.56$, $N = 18$) were not significantly different before and after pulling a double weighted haul seine. Power of this comparison was low, 0.06 for density and 0.08 for height, because of the small sample sizes.

A number of questions were raised during the conduct of the study regarding the location and methodology of DNR's experimental haul seining and the validity of extending this part of the study to commercial haul seining on the Susquehanna Flats. It was noted that experimental sites were adjacent to rocky shorelines and not in the area where commercial nets were hauled. The experimental sites were chosen to be comparable in depth and having an array of SAV densities. Although the shoreline was rocky, the actual experimental quadrats measured were relatively devoid of rocks and other debris, and from that perspective, quite typical of the area swept by commercial haul seines.

The other general criticisms were that the experimental net was much shorter than the commercial nets and was stepped on to keep the lead line on the bottom. Length of the seine was shortened from that used by commercial fishers to be manageable to DNR vessels and personnel. Observers from the DNR noted that the commercial netters did not step on the lead line until the seine had been fully pursed. Only during the final stages in which the fish were being herded into the pocket of the seine was there any attempt on the part of the haul seiners to keep the lead line in contact with the bottom. In this regard, the experimental seines simulated the commercial nets quite closely.

Another question that was raised concerned the weighting of the experimental net. The experimental net used by DNR personnel had a 43 g (1.5 oz) weight every 0.6 m (2 feet) for an average lead line weight of 72 g/m, roughly twice the lead line weight of one commercial net (37 g/m) and approximately three fourths the lead line weight of the other net (100 g/m).

Although it is true that during certain phases of haul seining the commercial nets exhibit more tension on the lead line compared to the hand hauled experimental net, DNR personnel observed that increased tension tends to raise the lead line, especially over depressions and troughs. Consequently, increased tension would have the tendency to keep the lead line from scouring and lessen the likelihood of SAV disruption. As confirmed by underwater video, even when the lead line was relatively "taut" and in full contact with the bottom, because of the length of the net, the lead line can be lifted with little effort and easily rode up and over the foot of the observer. Although it may seem counter-intuitive, increased tension adds no additional downward force to the lead line.

Commercial Haul Seine Observations

In 1996, twenty-one haul seine sets, encompassing 34 ha (84 acres), were made by commercial fishers on the Susquehanna Flats. The area haul seined during 1996 was less than 2% of the most recent estimate of SAV acreage in the Susquehanna Flats (Orth et al. 1995). We accompanied fishers on 16 of 21 (76%) trips during the 26 August - 29 November season (Table 12; Figure 10). Both crews filled their quotas by 10 September. Nine species of finfish were caught, but striped bass were predominant and were present in 94% of hauls (Table 12). No additional sets were made for other species.

The area fished by haul seiners was shallow (average depth 1 m or about 3 ft at low tide) with troughs as deep as 2.5 m (7.5 ft). The bottom was packed sand and SAV density was estimated to be between zero and ten plants per square meter where nets were pulled.

Although plants were observed in seines, biomass estimates of uprooted SAV were not made from them due to the small amount of SAV entangled and difficulty in determining whether seining was the cause of loose SAV. Quantities of loose SAV were observed both floating and settled on the bottom throughout the SAV growing season. These plants were captured by nets, and were indistinguishable from plants that may have been dislodged by seining. On several occasions, biologists/observers positioned themselves near clumps of rooted SAV and watched the approaching haul seine being pulled over them. In all cases, the seine rode over the long flexible strands of SAV without breaking or uprooting the plants. Underwater video taping of commercial seines showed the lead lines bending the SAV stems and passing over them.

Aerial Photography

By comparing photographs of commercial seining locations in August and September with photographs of the SAV beds in November, we determined that SAV beds were not impacted by commercial haul seining. No scarring of SAV beds or reduced density consistent with predicted seine impacts was visible on the photographs (R. Orth, VIMS, personal communication). Ten of 16 observed haul seine sets were within SAV beds (Figure 5). One was in a relatively high concentration of plants, five were pulled in moderately dense beds and four were pulled in the lowest density bed.

Commercial haul seining typically takes place in low density SAV beds. It has been the experience of DNR biologists that when seines are pulled through dense SAV beds, the lead line of the seine rolls into a compact "rope" of netting. The commercial fishers indicated that they avoid seining in dense SAV because of the same problem. Videos of commercial operations revealed that the lead line of the seines are in contact intermittently with the bottom. No dislodging of rooted plants by commercial or experimental nets was observed.

Significant interannual changes occur in the distribution of SAV in the Susquehanna Flats. Preliminary analysis of 1996 photographs reveal that some SAV beds dense in 1995 have become sparse while some sparse beds have increased in plant density. These annual changes are attributed to water quality, meteorological events or the reproductive biology of the SAV species present (R.

Orth pers. comm.).

Before and after photographs of experimental seine sites were taken for July sampling, but continuous cloud cover and high wind during the low tide "window" from September 1 - 17 prevented flights before the last experimental haul seine sample date. For this reason, and due to extensive line-intercept sampling already performed, low level aerial photography was not evaluated for experimental haul seine sites. Attempts were made to take "after" photographs during each low tide window after haul seiners stopped fishing on 12 September, but acceptable photographs could not be taken until 4 November due to poor water clarity and cloud cover.

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Table 1. Number of submerged aquatic vegetation quadrats sampled by treatment segments at experimental test sites. September 20 includes a haul in T-1 after additional weights were added.

Date	Site	Number of quadrats sampled Control	T-1	T-2	T-3	Total
09 July	Outfall	40	40	0	0	80
10 July	Cove	40	40	0	0	80
12 July	Stump Point	40	40	0	0	80
05 August	Outfall	20	10	40	0	70
06 August	Stump Point	20	10	40	0	70
07 August	Cove	20	10	40	0	70
18 September	Stump Point	20	10	40	40	110
19 September	Outfall	20	10	40	40	110
20 September	Cove	20	40	40	40	140
Total		240	210	240	120	810

Table 2. Percent of quadrats with an SAV species, by site and month. CDEM is coontail; ECAN, elodea; HDUB, water stargrass; HVER, hydrilla; MSPI, watermilfoil; NGUA, southern Naiad; NSPE, unknown Naiad; PPUS, slender pondweed; and VAME, wild celery.

Month	Location	Percentage by Species									Sample Size
		CDEM	ECAN	HDUB	HVER	MSPI	NGUA	NSPE	PPUS	VAME	
Cove	July	33	0	0	100	03	01	65	0	0	80
	August	09	0	0	94	04	01	30	0	03	70
	September	22	0	04	99	16	01	20	0	11	140
Outfall	July	19	0	0	94	04	03	20	01	0	80
	August	14	01	0	100	13	0	64	06	01	70
	September	05	0	02	100	10	0	41	0	03	110
Stump Point	July	01	0	03	05	29	0	0	0	90	79
	August	03	0	0	14	19	0	03	0	86	70
	September	01	0	04	11	06	06	01	0	69	109

Table 3. Comparison of proportion of quadrats containing a plant species before and after seining. Months and sites were combined. Confidence intervals (95% CI) were reported if significantly different from zero. f is effect size. $N = 180$; f_{min} was 0.30 for all comparisons; and power at f_a was > 0.99. CDEM is coontail; HVER, hydrilla; MSPI, water stargrass; NSPE, unknown Naiad; and VAME, wild celery.

Species	Treatment	Lower 95% CI	Mean	Upper 95% CI	f	Power
CDEM	Before	0.093	0.144	0.195		
	After	0.093	0.144	0.195	0	0
HVER	Before	0.633	0.700	0.767		
	After	0.621	0.689	0.756	0.05	0.10
MSPI	Before	0.079	0.128	0.176		
	After	0.034	0.072	0.110	0.10	0.24
NSPE	Before	0.182	0.244	0.307		
	After	0.177	0.239	0.301	0.05	0.10
VAME	Before	0.218	0.283	0.349		
	After	0.172	0.233	0.295	0.10	0.24

Table 4. Results of ANOVA testing the immediate effect of haul seining on $\log_e$-transformed plant density (plants per $m^2 + 1$). Treatments were never seined, before seining and after seining. DF = degrees of freedom. SS = sums of squares. MS = mean square. F is the F statistic.. Pr > F is the level of significance.

Source	DF	SS	MS	F	Pr > F
Model	26	127.29	4.90	9.13	0.0001
Error	570	305.56	0.54		
Type III Sums of Squares					
Month	2	7.86	3.93	7.33	0.0007
Treatment	2	9.36	4.68	8.73	0.0002
Site	2	61.59	30.80	57.45	0.0001
Treatment *Site	4	3.01	0.75	1.41	0.2307
Month* Treatment *Site	16	50.13	3.13	5.84	0.0001
Hypothesis Test with Type III MS for Month*Treatment *Site as an Error Term					
Treatment	2	9.36	4.68	1.49	0.2540

Table 5. Results of full ANOVA testing the immediate effect of haul seining on $\log_e$-transformed tallest plant height. Treatments were never seined, before seining and after seining. DF = degrees of freedom. SS = sums of squares. MS = mean square. F is the F statistic.. Pr > F is the level of significance.

Source	DF	SS	MS	F	Pr > F
Model	26	151.22	5.82	27.53	0.0001
Error	534	112.82	0.21		
Type III Sums of Squares					
Month	2	0.61	0.31	1.45	0.2346
Treatment	2	1.56	0.78	3.68	0.0258
Site	2	106.82	53.41	252.80	0.0001
Treatment *Site	4	2.16	0.54	2.55	0.0383
Month* Treatment *Site	16	10.36	0.657	3.07	0.0001
Hypothesis Test with Type III MS for Month*Treatment *Site as an Error Term					
Treatment	2	1.56	0.78	1.20	0.3267

Table 6. Results of reduced ANOVA testing the immediate effect of haul seining on $\log_e$-transformed tallest plant height. Treatments were never seined, before seining and after seining. DF = degrees of freedom. SS = sums of squares. MS = mean square. F is the F statistic.. Pr > F is the level of significance.

Source	DF	SS	MS	F	Pr > F
Model	8	140.27	17.53	78.20	0.0001
Error	552	123.77	0.22		
Type III Sums of Squares					
Treatment	2	1.49	0.74	3.31	0.0371
Site	2	128.36	64.18	286.23	0.0001
Treatment *Site	4	2.30	0.58	2.57	0.0372
Hypothesis Test with Type III MS for Treatment *Site as an Error Term					
Treatment	2	1.49	0.743	1.29	0.3697

Table 7. Results of full ANOVA (+ two month model) testing long-term effect of haul seining in July on log$_e$-transformed plant density (plants per m^2 +1). Transects were revisited during August and September. Treatments were never seined and after seining. DF = degrees of freedom. SS = sums of squares. MS = mean square. F is the F statistic.. Pr > F is the level of significance.

Source	DF	SS	MS	F	Pr > F
Model	17	65.08	3.83	7.89	0.0001
Error	349	169.40	0.48		
Type III Sums of Squares					
Month	2	9.09	4.54	9.36	0.0001
Treatment	1	0.05	0.02	0.10	0.7499
Site	2	20.76	10.38	21.386	0.0001
Treatment *Site	2	2.24	1.12	2.31	0.1010
Month* Treatment *Site	10	36.39	3.64	7.50	0.0001
Hypothesis Test with Type III MS for Month*Treatment *Site as an Error Term					
Treatment	1	0.05	0.05	0.01	0.9096

Table 8. Results of full ANOVA (+ one month model) testing long-term effect of haul seining in August on $\log_e$-transformed plant density (plants per m^2 + 1;). Transects were revisited during September. Treatments were never seined and after seining. DF = degrees of freedom. SS = sums of squares. MS = mean square. F is the F statistic. Pr > F is the level of significance.

Source	DF	SS	MS	F	Pr > F
Model	11	57.33	5.21	10.81	0.0001
Error	226	108.97	0.48		
Type III Sums of Squares					
Month	1	12.77	12.77	26.49	0.0001
Treatment	1	0.08	0.08	0.17	0.6783
Site	2	39.60	19.80	41.06	0.0001
Treatment *Site	2	0.30	0.15	0.32	0.7292
Month* Treatment *Site	5	4.53	0.91	1.88	0.0988
Hypothesis Test with Type III MS for Month*Treatment *Site as an Error Term					
Treatment	1	0.08	0.08	0.09	0.7741

Table 9. Results of full ANOVA (+ two month model) testing long-term effect of haul seining in July on $\log_e$-transformed tallest plant height. Transects were revisited during August and September. Treatments were never seined and after seining. DF = degrees of freedom. SS = sums of squares. MS = mean square. F is the F statistic.. Pr > F is the level of significance.

Source	DF	SS	MS	F	Pr > F
Model	17	107.18	6.30	32.42	0.0001
Error	336	65.33	0.19		
		Type III Sums of Squares			
Month	2	1.13	0.57	2.92	0.0555
Treatment	1	0.11	0.11	0.57	0.4527
Site	2	64.52	32.26	165.89	0.0001
Treatment *Site	2	1.08	0.54	2.77	0.6390
Month* Treatment *Site	. 10	9.12	9.12	4.69	0.0001
Hypothesis Test with Type III MS for Month*Treatment *Site as an Error Term					
Treatment	1	0.11	0.11	0.12	0.7357

Table 10. Results of full ANOVA (+ one model) testing long-term effect of haul seining in August on $\log_e$-transformed tallest plant height (cm). Transects were revisited during September. Treatments were never seined and after seining. DF = degrees of freedom. SS = sums of squares. MS = mean square. F is the F statistic.. Pr > F is the level of significance.

Source	DF	SS	MS	F	Pr > F
Model	11	46.918	4.26	21.81	0.0001
Error	208	40.67	0.20		
Type III Sums of Squares					
Month	1	0.90	0.90	4.62	0.0327
Treatment	1	0.003	0.003	0.01	0.9049
Site	2	39.13	19.57	100.07	0.0001
Treatment *Site	2	0.97	0.48	2.48	0.0861
Month* Treatment *Site	5	5.74	1.15	5.88	0.0001
Hypothesis Test with Type III MS for Month*Treatment *Site as an Error Term					
Treatment	1	0.003	0.003	0.00	0.9626

Table 11. Results of ANOVA power analyses. Table = Table of ANOVA results: f = effect, Power at f_a is power at an effect size of 0.50; and f_{min} is effect size where power = 0.95.

Variable	Seine Effect	Table	f	Power	Power at f_a	f_{min}
Density	Immediate	1	0.05	0.14	> 0.99	0.20
	+2 months	4	<0.01	<0.10	> 0.99	0.20
	+1 month	5	0.03	0.10	> 0.99	0.25
Height	Immediate	3	0.12	0.44	> 0.99	0.20
	+2 months	6	0.02	0.14	> 0.99	0.22
	+1 month	7	0.01	<0.10	> 0.99	0.26

Table 12. Commercial haul seine data. End time was equal to the approximate time the seine was closed off. List of abbreviations: SB: striped bass, CC: channel catfish, GS: gizzard shad, QC: quillback carp, C: common carp, SMB: smallmouth bass, WP: white perch, HS: hickory shad and AM: Atlantic menhaden. N/C = data not collected.

		Time		SAV Density		
Date	Fisher Crew Identification	Start	End	before	After	Fish Species Caught
26 August	1	1400	1415	slight	slight	SB, CC,GS,QC
26 August	2	1320	N/C	slight	slight	SB,CC,GS, C
26 August	1	N/C	N/C	slight	slight	SB, CC,GS,C
27 August	1	0800	0808	none	none	SB,CC
27 August	2	1350	1445	slight	N/C	SB, CC, C
27 August	1	1420	1431	slight	slight	SB,CC, C
28 August	1	1456	1505	slight	slight	SB,CC,C, SMB, WP
29 August	1	1648	1658	slight	slight	SB,CC,GS, C
30 August	1	DNR personnel not present during a single morning haul.				
30 August	1	1540	1556	slight	slight	SB,CC,SMB, WP
02 September	1	0850	0912	slight	slight	GS,HS
02 September	1	1137	1142	slight	slight	SB, CC,GS
02 September	2	1840	1858	slight	slight	SB,CC,GS
03 September	1	0930	0938	slight	none	SB, CC,GS, C,WP
03 September	1	1245	1255	slight	slight	SB,CC,GS,C, WP
04 September	1	DNR personnel not present - two hauls made on this date.				
05 September	2	1645	1700	none	none	SB,C
05 September	1	1637	1646	slight	slight	SB,GS,AM
10 September	1	DNR personnel not present- two hauls made on this date.				

Figure 1. Experimental study sites to assess the effects of haul seining on submerged aquatic vegetation in the upper Chesapeake Bay.

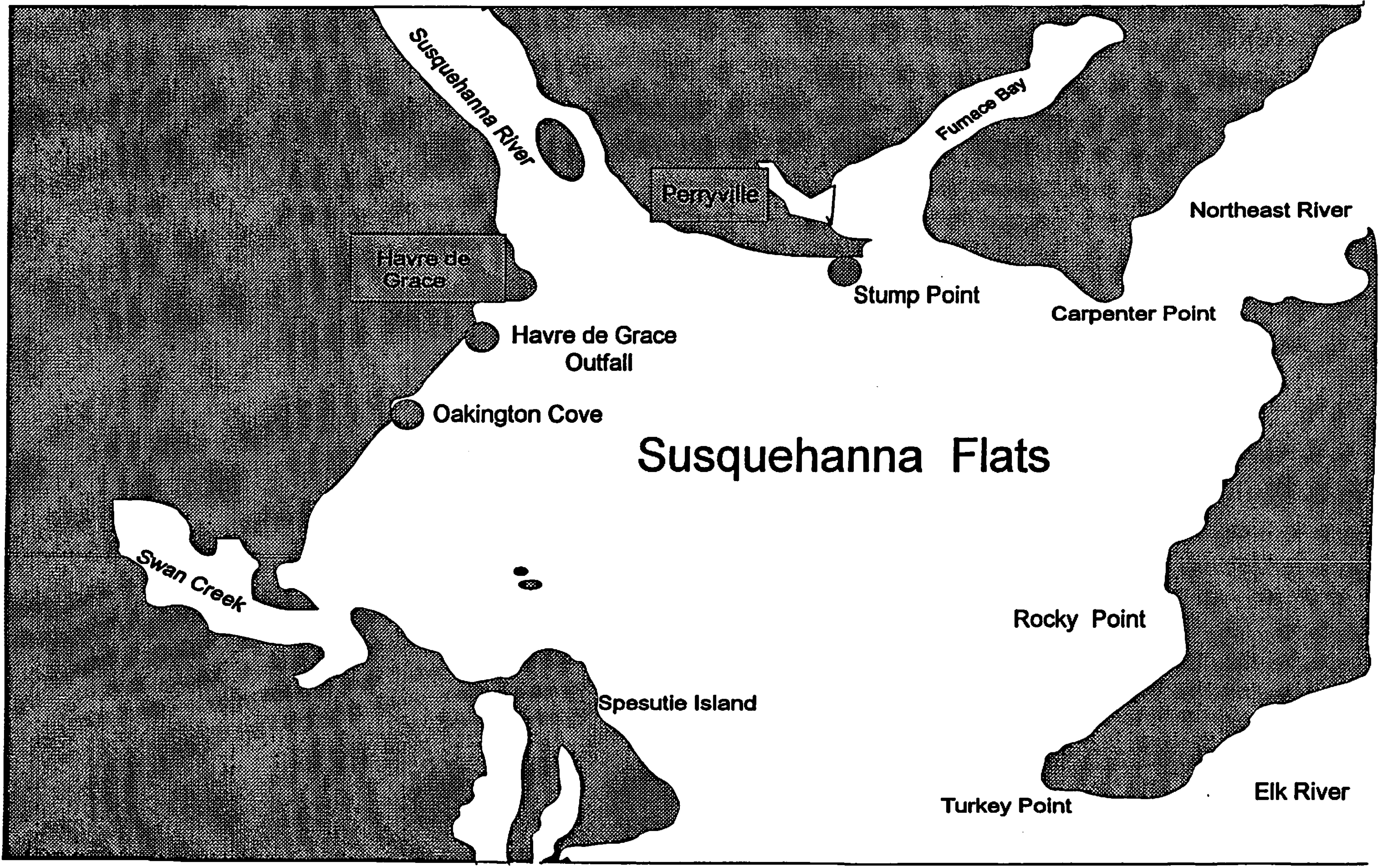


Figure 2. Side pocket commercial haul seine used by Maryland watermen on the Susquehanna Flats.

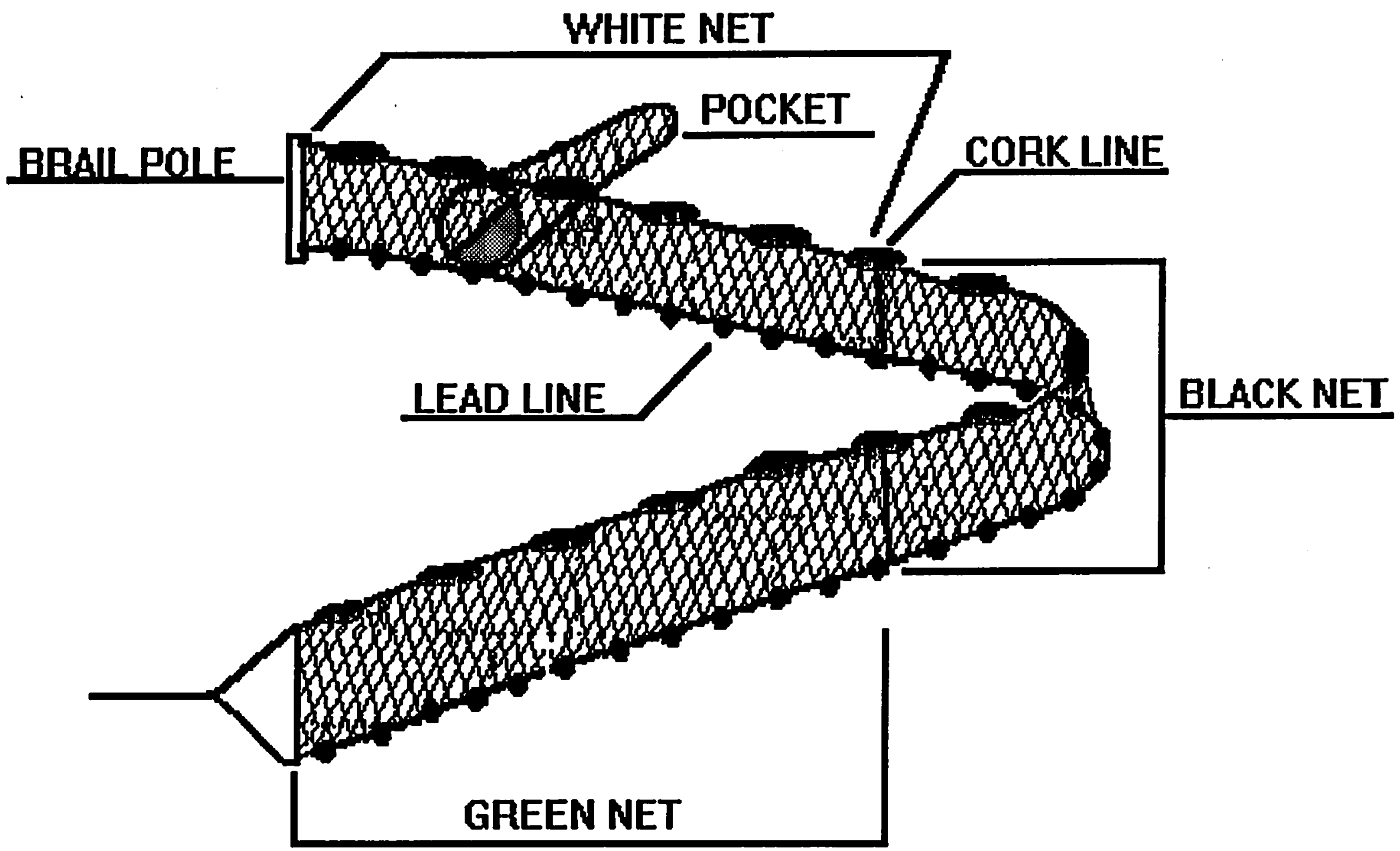


Figure 3. Center pocket commercial haul seine used by Maryland watermen on the Susquehanna Flats.

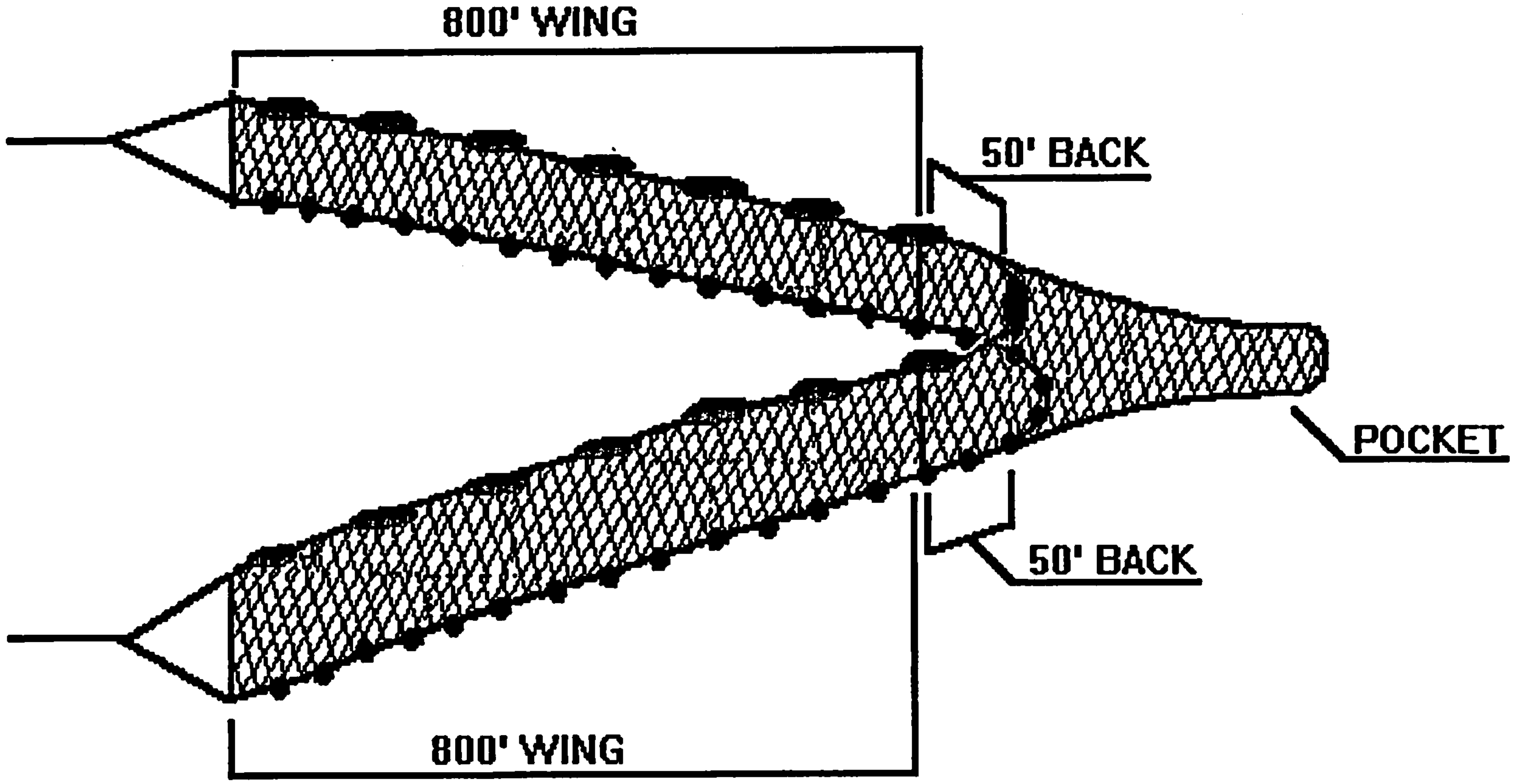
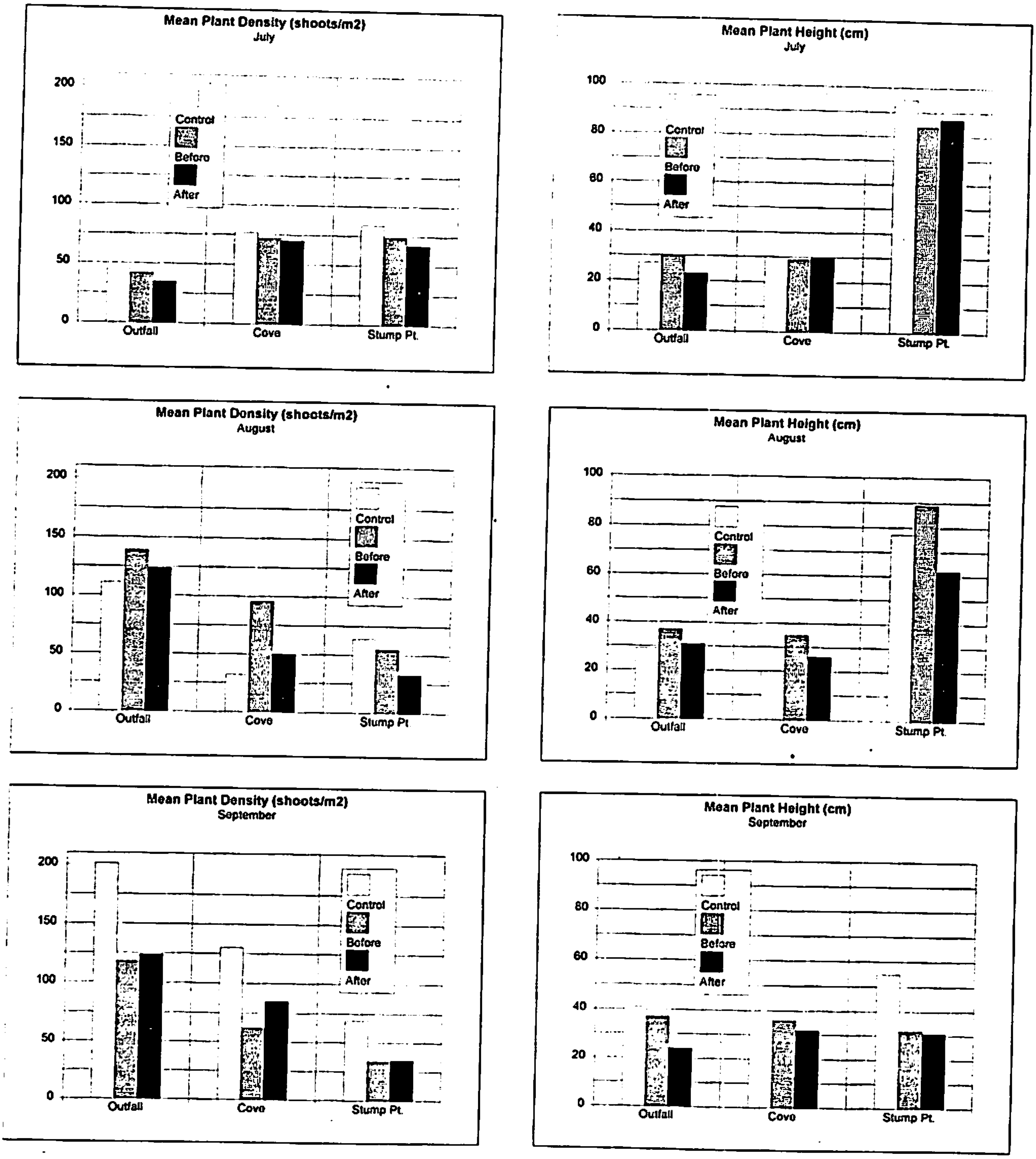


Figure 4. Submerged aquatic vegetation density and height at three experimental haul seine sites in three months in the Susquehanna Flats.



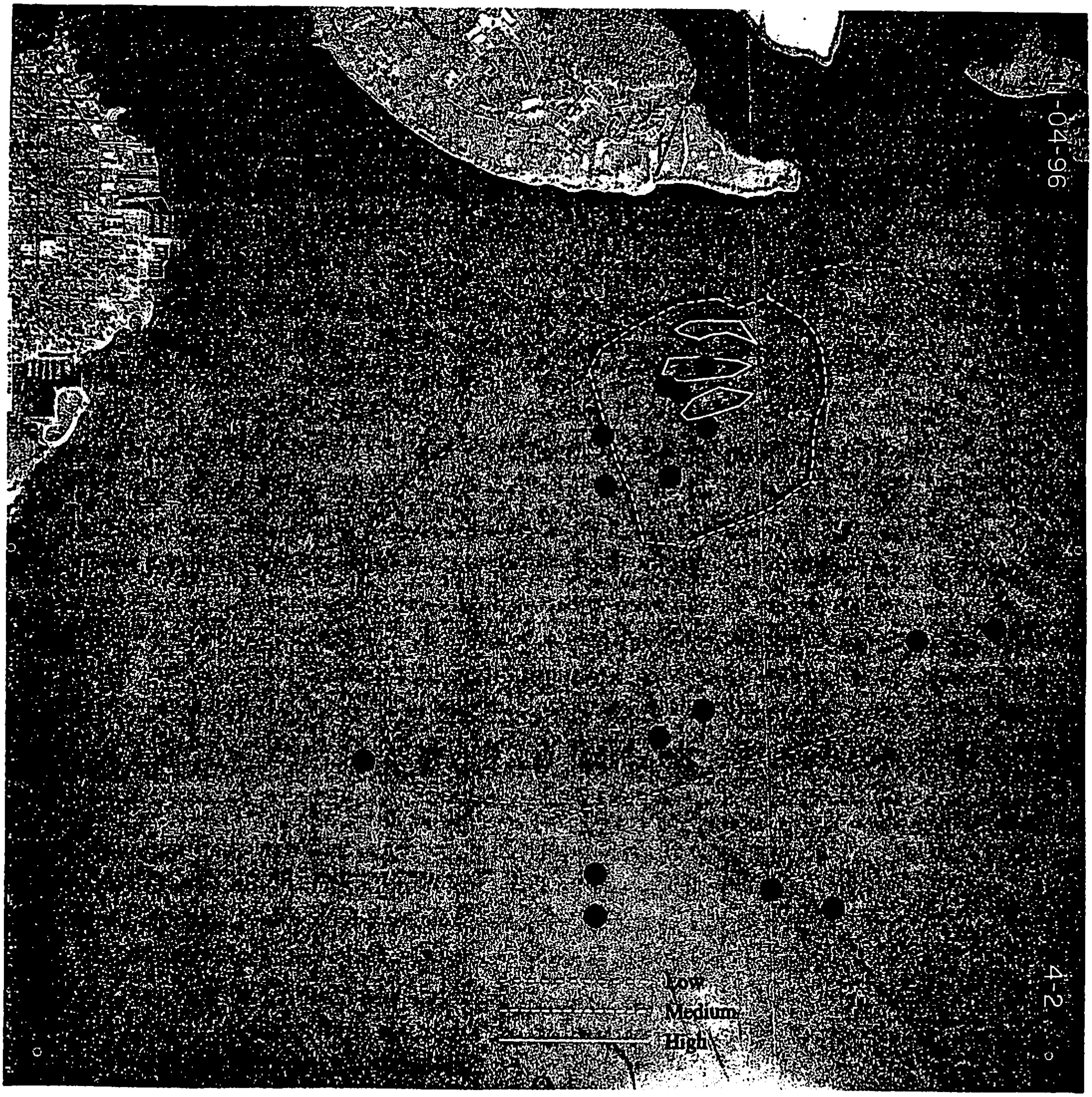


Figure 5. Submerged aquatic vegetation beds in the Susquehanna Flats, relative densities, and location of 16 commercial haul seine sites. August and September 1996.

Appendix 1. Description of commercial haul seines.

The haul seine used by fisher crew one was 529 m long (1736 ft) and had a total of sixteen - 27 cm (10.5 inches) diameter steel rings with 1,233 lead weights, each weighing 43 g (1.5 ounces). The seine consisted of three sections (Figure 2):

Section 1 (green net): 143 m (470 ft) long, 3.3 m (11 ft) wide, this section consisted of #18 twine, 10 cm (4 inch) stretch-mesh and had four rings 38 m (125 ft) apart. There were 540 evenly-spaced lead weights and 150-seven cm diameter (2.75 inch) styrofoam corks, four cm (1.5 in) long.

Section 2 (black net): 111 m (366 ft) long, 3.5 m (11.5 ft) wide, #18 twine, 8 cm (3 in) stretch-mesh, three rings approximately 37 m (122 ft) apart, 212 lead weights and 201 corks that had a diameter of seven cm (2.75 in) and a length of 4 cm (1.5 in).

Section 3 (white net): 275 m (900 ft) long, 2.4 m (8 ft) wide, #22 twine, 6 cm (2.5 in) stretch-mesh, nine rings approximately 31 m (100 ft) apart, 481 lead weights and 482 corks 10 cm (3.75 in) diameter and a length of 4 cm (1.5 in). The cone-shaped pocket is located within section three and is 14 m (45 ft) from the brail pole. It has 12 corks and leads and has a circumference of 4.3 m (14 ft) and is 6.4 m (21 ft) long. A weight of several kilograms (approximately 5 lbs) is tied to a rope at the end of the pocket to keep the pocket open.

The haul seine operated by fisher crew two was 488 m (1600 ft) long (Figure 3). The seine had equal length wings of 229 m (750 ft) attached to back sections joined by the pocket. The wings measure 4.6 m (15 ft) wide and consist of #18 twine and 7.6 cm (3 in) stretch-mesh. Twenty-five centimeter (10 in) diameter steel rings were located 30.5 m (100 ft) apart, 640 lead weights were located every 76 cm (2.5 ft) weighing 28 g (1 ounce) and there were 400 corks every 61 cm (2 ft).

The two back sections are 15.3 m (50 ft) long, 4.6 m (15 ft) wide consisting of #24 twine with 25 corks. The pocket on this seine is 7.6 m (25 ft) long, consists of #24 twine and has 57 g (2 oz) lead weights every foot on the lead line.

Appendix 2. Means of loge-transformed plant densities (+1) and tallest plant heights (cm) by ANOVA model and treatment.

Model	Treatment	Density	Height
		Normally Weighted Seine	
Immediate	Neither	1.86	3.61
	Before	1.99	3.67
	After	1.66	3.50
+ Two Month	Never	1.86	3.61
	After	1.86	3.58
+ One Month	Never	1.82	3.63
	After	1.77	3.66
		Double Weighted Seine	
Immediate	Before	2.57	3.21
	After	2.18	3.35