Relative Abundance Sampling of Juvenile Atlantic Sturgeon in the Hudson River

Final Study Report

by

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SUMMARY

The goal of this study was to conduct the preliminary sampling necessary to make recommendations on sampling methodology for a juvenile Atlantic sturgeon population monitoring program by the NYSDEC Hudson River Fisheries Unit. Specific objectives were to determine the location, time of year, sampling methodology, and amount of sampling effort needed for effective population monitoring.

Sampling was conducted in Newburgh and Haverstraw Bays of the Hudson, as these were known areas of juvenile Atlantic sturgeon concentrations. We sampled spring (March – April) and fall (October – November) seasons beginning in October 2003 and ending in November 2005. Both bays were generally stratified according to bottom type and depth: hard/deep, hard/shallow, soft/deep, and soft/shallow. Juvenile Atlantic sturgeon were sampled using anchored gill nets of 76, 102, and 127 mm (3, 4, and 5 inch) stretch mesh deployed in a block pattern at randomly chosen sites within habitat strata. We set the nets perpendicular to the shore in Haverstraw Bay, but experimented with parallel vs. perpendicular sets in Newburgh Bay to determine if the orientation of the nets influenced catches of juvenile Atlantic sturgeon. We also compared catches during slack tides vs. running tides.

A total of 562 juvenile Atlantic sturgeon were caught during the course of this study. The majority of these fish were caught in Haverstraw Bay. Frequency of occurrence and CPUE of juvenile Atlantic sturgeon was consistently highest in soft/deep areas of Haverstraw Bay. Seasonal comparisons showed CPUE within soft/deep areas of Haverstraw Bay was greatest during mid to late spring.

Although there was a high degree of overlap in the size distributions of juvenile Atlantic sturgeon caught in each gill net mesh size, 127 mm stretch mesh tending to catch larger fish than 76 or 102 mm stretch mesh. Tidal state (slack vs. running) and net orientation (parallel vs. perpendicular) did not influence catches of juvenile Atlantic sturgeon.

For future monitoring of relative abundance of juvenile Atlantic sturgeon in the Hudson River we recommend sampling in soft/deep areas of Haverstraw Bay during mid to late spring seasons when water temperatures exceed 4°C using 76, 102, and 127 mm stretch mesh anchored gill nets. Sample sizes required to detect a given rate of CPUE change over time were also calculated and may be used by the Hudson River Fisheries Unit to decide how much effort to expend during future monitoring.

INTRODUCTION

The Atlantic sturgeon (*Acipenser oxyrinchus*) historically supported a valuable commercial fishery in the Hudson River estuary from the late 19th century through 1996. The fishery in the estuary targeted adult sturgeon for both meat and caviar, and coastal fisheries targeted sub-adults for meat. The commercial fishery can be characterized by a period of high harvest (pre- 1900s), followed by a period of minimal harvest and some population recovery (1900 – 1979), a renewed effort in the fishery with high harvest levels (1980 – 1992), and finally another decline (1993 – 1996) (ASMFC 1998a; Bain et al. 1999). As data became available in the 1990s, evidence of overfishing became apparent and the NYSDEC placed a moratorium on the Hudson River fishery in 1996. The Atlantic States Marine Fisheries Commission (ASMFC) followed suit in 1998 by amending the 1990 Atlantic sturgeon fisheries management plan placing a coast wide moratorium on the species (ASMFC1998b).

The Atlantic sturgeon is a long lived species with males beginning to mature at age 10 and females at age 14 (Van Eenennam et al. 1996). The population historically supported 40 year classes in the spawning population and the ASMFC (1998a) recommended that the moratorium remain in place until it can be documented that there are at least 20 protected year classes of spawning females in each stock along the Atlantic coast. Thus, the moratorium should remain in effect for a minimum of 38 years from the initiation of the moratorium on a particular stock. For the Hudson stock, the moratorium should remain in place until at least 2034.

The life history of Atlantic sturgeon makes monitoring population trends through time difficult (Dovel and Berggren 1983; Bain 1997, 1999). Male Atlantic sturgeon may

spawn every year (Van Eenennam et al. 1996), but females have an interspawning period of 3 – 5 years (Smith 1985). The differences between the sexes with respect to age at maturity and spawning periodicity present problems for indexing adult abundance.

The early juvenile stages provide the best opportunity for population monitoring. Juveniles may remain in the river for as long as six years, but may emigrate to marine environments as early as age 2 (Dovel and Berggren 1983; Peterson et al. 2000). There have been two population estimates of age-1 Atlantic sturgeon in the Hudson River. Dovel and Berggren (1983) estimated the 1976 cohort at 25,647 (95% confidence limits = 13,206 – 53,039) individuals in 1977 and Petersen et al. (2000) estimated the 1994 cohort at 4,314 (95% confidence limits = 1,916 – 10,473) individuals in 1995, suggesting declining recruitment in the Hudson River. The large confidence intervals from Petersen et al. (2000) illustrate the difficulty in obtaining precise population estimates in a large river system such as the Hudson River.

Fishery independent data on relative abundance of juvenile Atlantic sturgeon prior to emigration from the Hudson River Estuary have been collected annually by Hudson valley utility companies and other researchers since 1974. The most extensive utility time series of data were obtained by one-meter epibenthic sled and by three-meter beam trawls in a fall shoals survey. These data suggest a slight increase in abundance in response to the fishery closure in 1996 (New York State's Atlantic sturgeon Annual Report for 2004 to the Atlantic States Marine Fisheries Commission).

Although the utility data are extensive, the programs were not designed to sample Atlantic sturgeon. Therefore NYSDEC contracted a preliminary study in 1998 to Cornell University (Bain et al. 1999). This sampling occurred from April through August, did

not sample juveniles during the fall or locate any over-wintering concentrations of fish, and limited sampling effort to only slack tides. To supplement this preliminary study, NYSDEC started a sampling program in the spring and fall of 2000 to identify times and locations for optimal catches of juvenile Atlantic sturgeon prior to emigration from the estuary. Sampling was discontinued in 2001 following staff reductions. Development and implementation of a reliable monitoring program is needed to better evaluate the population response to the current fishery closure.

The present historically low abundance of juvenile Atlantic sturgeon in the Hudson River makes precise estimation of population sizes difficult (e.g. Petersen et al. 2000). Wide confidence intervals are indicative of the low probabilities of recapture associated with rare species in a large river system. Therefore a more practical approach for long term monitoring of population trends would be annual indices of relative abundance, such as mean catch-per-unit-effort (CPUE), from a standardized sampling design.

The objectives of this study were to (1) assess seasonal habitat use by juvenile Atlantic sturgeon with respect to bottom type and water depth in Newburgh and Haverstraw bays; (2) determine effective methods of fishing anchored gillnets to catch juvenile Atlantic sturgeon; (3) assess size-selectivity of gillnets for juvenile Atlantic sturgeon; and (4) provide estimates of sample size requirements for future monitoring to detect population trends.

METHODS

Sampling effort was concentrated in Newburgh and Haverstraw bays of the Hudson River (Figure 1). Newburgh and Haverstraw bays are areas of known

concentrations of juvenile Atlantic sturgeon (Dovel and Berggren 1983; Bain et al. 1999) and we believe these regions provide the greatest probability of capturing juveniles.

Substrate and depth influence Atlantic sturgeon distributions (Haley et al. 1996; Bain 1997; Haley 1999). We used bottom type and bathymetry data from the Lamont Dougherty Earth Observatory to spatially stratify each bay (Bell et al. 2006; Nitsche et al. 2004). Strata were identified as combinations of bottom type and depth: hard/deep, hard/shallow, soft/deep, soft/shallow (Appendix – Catch Maps). Areas of high backscatter from sidescan sonar corresponded to "hard" substrates while areas of low backscatter corresponded to areas of "soft" substrates. Hard substrates typically consisted of compacted sand, rock, gravel, and remnant oyster beds, while soft substrates consisted of silt and mud. Deep areas in Newburgh Bay were considered those with depths ≥ 30 feet. Because Haverstraw Bay is generally shallower than Newburgh Bay, deep areas were considered those with depths ≥ 20 feet.

Sampling occurred during five time periods: fall 2003, spring 2004, fall 2004, spring 2005, and fall 2005. Fall sampling occurred from October through November and spring sampling occurred from March through April.

We used 61 m (200 ft.) x 2.4 m (8 ft.) anchored gillnets with stretch mesh sizes of 76, 102, and 127 mm (3, 4, and 5 inches). These combined mesh sized effectively capture juvenile-sized Atlantic sturgeon (NYSDEC *unpublished data*; Bain et al. 1999). A "net set" consisted of three nets, one of each mesh size. Nets were set parallel to one another with a distance of at least 61 m between nets and the group of three nets was set perpendicular to the shore. Nets were fished for a minimum of two hours. Net sets were made during both slack and running tides. Tidal currents were much stronger in

Newburgh Bay compared to Haverstraw Bay because Newburgh Bay is less than half the width of Haverstraw Bay. This often resulted in the nets becoming fouled with debris and not fishing effectively. To determine if this problem could be overcome, we set half of net sets parallel to the shore during spring 2005 and fall 2005 seasons to compare catches between methods of fishing. All net sets in Haverstraw Bay were made perpendicular to shore during all seasons.

Water quality parameters were measured using a YSI ® 556 multiprobe system. Surface and bottom temperature, D.O., pH, salinity, and specific conductance were measured at each net set.

Sampling effort during fall 2003 and spring 2004 was allocated among habitat types according to their respective proportional contribution to total available habitat within Newburgh and Haverstraw Bays. Within each habitat stratum random locations for net sets were generated in a GIS prior to sampling. The goal of the first year of study was to determine which habitat stratum was most used by juvenile Atlantic sturgeon. Sampling in remaining seasons then focused half of the effort in most preferred habitat (referred to as targeted habitat) and half in random locations outside of the preferred habitat to test the first year's results and to gain estimates of mean CPUE and associated variances.

Captured Atlantic and shortnose sturgeon were held in a live well until processing. Catches from each mesh size were held separately to later compare size distributions captured by each mesh size. Atlantic sturgeon were weighed (0.01 kg), measured (1 mm, total and fork lengths), tagged with both passive integrated transponder (PIT) tags and Carlin tags, and had a small section (< 5 mm) removed from the leading

edge of the left pectoral spine for aging purposes. Each fish was also inspected for tags from previous research or sampling efforts. If a PIT or Carlin tag was not present, we applied one. If a fish was recaptured, but was missing one of the two tags, then a new tag was applied. Shortnose sturgeon were processed in the same manner, except no spine sample was taken.

Statistical Analysis

Presence/absence data for juvenile Atlantic sturgeon were analyzed using a chi-square test to determine if the proportion of net sets resulting in a catch of at least one sturgeon was different among habitat strata during fall 2003 and spring 2004 seasons. Likewise, a chi-square test was used to determine if presence/absence data differed between targeted habitat and random areas in later seasons.

Catch-per-unit-effort was calculated as the total catch of a net set (catch from all 3 nets) divided by the sum of the effort of all nets within a net set (m^2 of net deployed x hours). Summary statistics, such as mean and median CPUE and associated variances, were calculated from CPUE values from individual net sets. Catch-per-unit-effort data were not normally distributed, therefore a one-tailed Wilcoxon two-sample test was used to determine if CPUE was higher in the targeted habitat compared to random areas during fall 2004, spring 2005, and fall 2005 seasons. A Wilcoxon two-sample test was also used to compare CPUE between seasons. When comparing seasonal CPUE data, we only used data coming from targeted habitat to eliminate the confounding effects of less preferred habitat.

The tidal effect on presence/absence and CPUE of juvenile Atlantic sturgeon was analyzed for targeted habitats. Again, random areas were excluded from this analysis to

prevent confounding effects of less preferred habitat. Data were pooled across years within a season (fall or spring). Each net set was classified as either set on "slack" or "running" tide. A net set was considered "slack" if the approximately two hour duration of soak time overlapped a slack tide. A chi-square test was used in analyzing presence/absence data and a one-tailed Wilcoxon two-sample test was used to determine if CPUE was higher for "slack" net sets compared to "running" net sets.

Spearman rank correlation was used to examine relationships between water quality parameters and CPUE each season. Only data from targeted areas were used to avoid confounding differences in physical habitat preference. Correlation analysis was run separately for each season and for all seasons combined within a bay.

We plotted cumulative CPUE from targeted habitat on Julian date to determine if there was any trend to CPUE as each sampling season progressed. Cumulative CPUE was calculated for each Julian date by dividing the cumulative catch for the season by the cumulative amount of effort expended for the season by a particular date. These data were compared to plots of temperature on Julian date each season.

Differences in the size of juvenile Atlantic sturgeon captured in each mesh size were assessed using a nonparametric median test. In this analysis, data from all seasons were pooled. An alpha level of 0.10 was used in all of the above hypothesis tests (Table 1).

Recommended sample sizes for continued monitoring were determined according to methods described in Gerrodette (1987) and using the computer program TRENDS (Gerrodette 1993). The software was used to determine the required coefficient of variation (CV) needed to detect a given annual rate of increase in CPUE for a given

number of years of monitoring at a given level of statistical power. The number of samples (net sets) required each year was then equal to $\left(\frac{CV_o}{CV_r}\right)^2$ where CV_o was the CV found during this study and CV_r was the required CV. Required sample sizes were determined for monitoring efforts of 10 – 20 years, rates of increase of 5 – 100% per year, annual sampling, and biennial sampling at powers of 80 and 95%.

Given that CPUE was greatest during spring season in soft/deep areas of Haverstraw Bay, and that it increased once water temperatures reached 4°C (see results), we felt this was the optimum time to sample in a long term monitoring program. To test this assumption data from Julian dates < 80 (before March 20) were deleted and presence/absence and CPUE data analysis were conducted again. Required sample sizes were then computed assuming an initial CV from soft/deep areas during spring 2005.

RESULTS

During the course of the study, a total of 562 wild juvenile Atlantic sturgeon were tagged and released. The majority were caught in Haverstraw Bay during all seasons. No juvenile Atlantic sturgeon were caught in Newburgh Bay during spring seasons.

Presence/Absence of juvenile Atlantic sturgeon

There were significant differences in the occurrence of juvenile Atlantic sturgeon among habitat strata in Haverstraw and Newburgh Bays (Table 2). Fall 2003 data showed a preference by Atlantic sturgeon for soft/deep areas of Haverstraw Bay (X^2 = 6.65, p = 0.08) with 64% of net sets in this strata capturing at least one Atlantic sturgeon. Presence in other strata ranged from 25 – 27%. In Newburgh Bay, Atlantic sturgeon were only caught in deep areas, regardless of substrate type. During the spring 2004

season, Atlantic sturgeon again tended to be caught more frequently in soft/deep areas of Haverstraw Bay (61% of net sets), but these results were not significant ($X^2 = 5.74$, $p = 0.12$) and hard/deep also had a relatively high occurrence of Atlantic sturgeon with 50% of net sets catching at least one individual. Combining fall 2003 and spring 2004 data showed that overall, there was a preference for soft/deep areas in Haverstraw Bay ($X^2 = 11.78$, $p = 0.01$) with 62% of net sets catching fish. Due to extreme problems with gear fouling in Newburgh Bay during spring 2004 sampling, no Atlantic sturgeon were caught and effort was greatly reduced in this area.

The occurrence of Atlantic sturgeon during fall 2004 and spring 2005 agreed with the results of the first year of study. Soft/deep areas in Haverstraw Bay during fall 2004 yielded the greatest frequency of catches with 66% of net sets catching at least one individual compared to 28% in random areas ($X^2 = 9.04$, $p < 0.01$). The total numbers of individual fish caught were equivalent between soft/deep and random areas (56 and 51 individuals respectively), but catches were much more consistent in soft/deep areas. Only seven Atlantic sturgeon were caught in Newburgh Bay during fall 2004, all of which were caught in deep areas. Spring 2005 again showed soft/deep areas of Haverstraw Bay were most preferred with 78% of net sets catching fish compared to 39% in random areas ($X^2 = 11.2$, $p < 0.01$). Spring 2005 sampling also yielded the greatest number of Atlantic sturgeon caught within a season; 104 were caught in soft deep areas and 65 were caught in random areas.

Net orientation had no effect on catching Atlantic sturgeon in Newburgh Bay ($X^2 = 0.49$, $p = 0.49$). Due to poor weather conditions and problems with our boat during spring 2005, very little sampling effort was made in Newburgh Bay with 5 parallel and 5

perpendicular net sets made. None of these captured any Atlantic sturgeon. During fall 2005, 19 parallel and 19 perpendicular sets were made, of which 7 and 5, respectively, caught Atlantic sturgeon.

Fall 2005 data in Haverstraw Bay did not agree with previous seasons. There was no difference in presence/absence data from soft/deep vs. random areas ($X^2 = 2.04$, $p = 0.15$) and only 13% of net set in soft/deep areas caught Atlantic sturgeon.

Pooling presence/absence data by season (fall or spring) showed an overall effect of habitat on the occurrence of Atlantic sturgeon in Haverstraw Bay (Table 2). During fall seasons 48% of net sets in soft/deep areas caught Atlantic sturgeon compared to 28% in other areas ($X^2 = 6.98$, $p < 0.01$). This difference was greater during spring seasons with 71% of soft/deep sets catching Atlantic sturgeon compared to 36% in other areas ($X^2 = 17.13$, $p < 0.01$).

There was no significant difference in occurrence of Atlantic sturgeon between net sets occurring on a running vs. a slack tide in either Haverstraw or Newburgh Bay (Table 3).

Catch-per-unit-effort of juvenile Atlantic sturgeon

Catch-per-unit-effort tended to be highest in soft/deep areas of Haverstraw Bay. When each sampling season was analyzed separately, soft/deep areas had the highest CPUE during both fall 2004 and spring 2005 seasons (one-tailed Wilcoxon two-sample test: $p = 0.02$ and $p < 0.01$, respectively). However, CPUE was actually higher in random areas compared to soft deep areas during fall 2005 (one-tailed Wilcoxon two-sample test: $p = 0.10$). Analysis of CPUE data pooled across years (Table 4) by season showed soft/deep areas in Haverstraw Bay yielded the overall highest CPUE for both fall (one-

tailed Wilcoxon two-sample test: $p = 0.02$) and spring seasons (one-tailed Wilcoxon two-sample test: $p < 0.01$).

Spring seasons had a higher CPUE than fall seasons in Haverstraw Bay (two-tailed Wilcoxon two-sample test: $p < 0.01$). Spring seasons in soft/deep areas also tended to have the lowest variability in CPUE as indexed by the coefficient of variation (Table 4).

The lack of catches of juvenile Atlantic sturgeon in Newburgh Bay negated the analysis of catch-per-unit-effort data in this region. Atlantic sturgeon were only captured in deep areas. There was also no difference in presence/absence data when comparing perpendicular vs. parallel net sets.

Correlation of CPUE and water quality

Spearman rank correlations of CPUE with water quality data showed inconsistent results (Table 5). Significant correlations were either restricted to a single season, or were inconsistent between Newburgh and Haverstraw Bays. For example, salinity was negatively correlated with CPUE in Haverstraw Bay during fall 2003 and fall 2005, but was positively correlated with CPUE in Newburgh Bay during fall 2005. Likewise, temperature was positively correlated to CPUE in Newburgh Bay during fall 2005, but had no correlation with CPUE in Haverstraw Bay during fall 2005. Fall 2005 and overall correlations for Newburgh Bay showed positive relationships between CPUE and temperature, specific conductance, and salinity, and a negative correlation with dissolved oxygen. Fall 2005 yielded the greatest catches of Atlantic sturgeon in Newburgh Bay and this period also corresponded to when the highest values of temperature, specific conductance, and salinity, and the lowest values of dissolved oxygen were recorded in

Newburgh Bay. Significant correlations with dissolved oxygen are likely spurious because at no time did dissolved oxygen drop below 5 mg/l.

Although correlations of CPUE of individual net sets and water quality did not show consistent correlations with temperature, plots of cumulative CPUE on Julian day showed a distinct pattern during the spring seasons as temperatures warmed (Figure 2). Cumulative CPUE increased sharply in Haverstraw Bay by Julian day 80 (March 20) in both spring 2004 and spring 2005 seasons. This increase corresponded to when temperatures began to exceed 4°C. No discernable pattern in CPUE was seen during fall seasons in Haverstraw or Newburgh Bay.

Analysis of pooled data from spring 2004 and spring 2005 for Julian dates ≥ 80 supported the observation of increased catches as water temperature exceeded 4°C. Again, juveniles Atlantic sturgeon occurred more frequently in soft/deep areas compared to other areas ($X^2 = 15.91$, $p < 0.01$) and CPUE was significantly higher in soft/deep areas (one-tailed Wilcoxon two-sample test: $p < 0.01$). The percentage of soft/deep net sets catching juvenile Atlantic sturgeon increased from 71% to 80% when only considering data from Julian dates ≥ 80.

Size composition of Atlantic sturgeon catches between seasons

Size composition of juvenile Atlantic sturgeon varied through time (Figure 3). Length frequency histograms from fall 2003 and spring 2004 seasons showed a bimodal size distribution in Haverstraw Bay with the first mode occurring at approximately 450 mm and the second mode at 575 mm fork length. However, the first mode dissipated in later seasons in Haverstraw Bay. Atlantic sturgeon caught in Newburgh Bay tended to be

smaller than those caught in Haverstraw Bay (Wilcoxon two-sample test: $p = 0.01$) and a bimodal size distribution was evident for Newburgh Bay during fall 2005.

Size composition of Atlantic sturgeon among gill net mesh sizes

All mesh sizes caught a wide range of juvenile Atlantic sturgeon (Figure 4). More fish were caught in 102 and 127 mm stretch mesh nets compared to the 76 mm mesh net. Although the size distributions of Atlantic sturgeon caught in each mesh size overlapped to a large degree, there was an overall significant difference in size distributions (Median Test: $p = 0.02$). The size distributions in 76 and 102 mm stretch mesh nets were equivalent (Median Test: $p = 0.19$), but 127 mm stretch mesh captured larger Atlantic sturgeon than both the 76 mm stretch mesh (Median Test: $p = 0.02$) and 102 mm stretch mesh (Median Test: $p < 0.01$).

Recaptures of juvenile Atlantic sturgeon

Of the total sturgeon tagged and released during this study, only 13 individuals were recaptured (Table 5). Two of the 13 (PIT tags 4310514A15 and 436008372C) recaptures were tagged in Haverstraw Bay and recaptured in Newburgh Bay. One individual (Carlin tag 16086) was tagged in Newburgh Bay and recaptured in Haverstraw Bay. The remaining 10 individuals were both tagged and recaptured in Haverstraw Bay. The number of days between marking and recapture ranged from 18 to 708 days. Specific growth rates of fish recaptured in a different season from when they were originally tagged, averaged 0.0008 mm FL/d (range = 0.0002 – 0.0019) and 0.0022 kg/day (range = -0.0004 – 0.0014). We also recaptured one Atlantic sturgeon with the remnants of a Carling tag wire still attached, but the numbered plastic tag was missing,

no PIT tag was detected, and it had a scar from a previous spine sample. This fish then had new tags applied prior to release.

We recaptured three shortnose sturgeon and two hatchery produced Atlantic sturgeon. A total of 228 shortnose sturgeon were tagged and released. One of the recaptured shortnose sturgeon (PIT tag 460D561F7B) was tagged and recaptured during the fall 2004 season in Haverstraw Bay. The other recaptured shortnose sturgeon (PIT tag 2270520341 and 22022761D) were tagged by Cornell in 1995 in Esopus Meadows and recaptured by us in Haverstraw Bay. One of the hatchery origin Atlantic sturgeon (PIT tag 423B370E61, Carlin tag 16728) had been stocked at the Haverstraw Bay County Park in September 2004. The other hatchery origin fish had a left pelvic fin amputation and we assumed this fish was released as a one year old during the 1994 experimental stocking by NYSDEC and the Northeast Fishery Center. All fish stocked in 1994 were implanted with a coded wire tag, but we did not have a coded wire tag detector with us to confirm its origin.

Sample size requirements

Sample size requirements were estimated based on an initial CV from soft deep areas in Haverstraw Bay during the mid to late spring 2005. By only considering data collected on Julian dates ≥ 80, the spring 2005 CV on mean decreased from 1.108 to 1.019.

Curves depicting sample size requirements were created for various annual rates of CPUE increase (Figure 5) and durations of population monitoring for 80 and 95% power (Table 7). In general, as the duration of population monitoring and the annual rate

of CPUE increases, the number of required samples decreases. Also, if sampling were to occur on a biennial basis (i.e. every other year) the number of samples increases.

DISCUSSION

Juvenile Atlantic sturgeon appear to exhibit seasonal movements within the Hudson River. Dovel and Berggren (1983) suggested a downstream fall migration of juvenile Atlantic sturgeon once water temperature drops below 20°C and that the Haverstraw/Tappan Zee region of the river was an area of over wintering concentrations. Once water temperatures warm in the spring juvenile fish which have not yet out migrated may move up river from over wintering areas (Dovel and Berggren 1983). Our fall and spring sampling periods likely bracketed the time at which juvenile Atlantic sturgeon were entering and leaving this over wintering habitat. Bain et al. (1999) suggested south Newburgh Bay was an area of concentration for age-1 Atlantic sturgeon during the summer months. If this is true, it is possible that fish which may be congregated in south Newburgh Bay during the summer months moved downstream by the time of our sampling in October – November because we tended to catch few fish in this area during fall 2003 and fall 2004 sampling periods compared to Haverstraw Bay.

Our results from fall 2005 differed from those of either fall 2003 or 2004. Summer 2005 experienced drought conditions and temperature and salinity were at their highest recorded levels in both bays at the beginning of the fall 2005 season. Our greatest catches of juvenile Atlantic sturgeon in Newburgh Bay occurred at the beginning of fall 2005 sampling. As water temperatures dropped, so did our catches in this area. Conversely, catches in Haverstraw Bay during fall 2005 were much lower than in

previous years during the early fall 2005 season and we recorded salinities of > 6.0 ppt and water temperatures >20°C at this time. We did not capture any Atlantic sturgeon in typically preferred soft/deep areas of Haverstraw Bay until October 24. The drought conditions of 2005 may likely have delayed the downstream fall migration described by Dovel and Berggren (1983) and were responsible for the resulting fall 2005 catches in Newburgh and Haverstraw Bays.

Soft/deep areas of Haverstraw Bay yielded the most consistent catches of juvenile Atlantic sturgeon. Haley (1999) also showed a strong preference by juvenile Atlantic sturgeon for deep water and they also preferred areas of mixed silt substrates, which would correspond to our "soft" classification. These areas may be associated with higher abundance of preferred food of juvenile Atlantic sturgeon (Haley 1999). Although soft/deep areas were those most frequently used, some of the largest catches in a single net set came from areas with hard bottoms and shallow depths (< 20 ft.) (See Appendix – Catch Maps). Catches outside soft/deep areas were much more variable than those in soft/deep areas and it is possible that when relatively large catches were encountered in non-soft/deep areas that the fish were migrating through such areas as opposed to using them as preferred habitat.

Size composition of juvenile Atlantic sturgeon varied through time and between bays. The bimodal size distribution seen during fall 2003 and spring 2004 seasons in Haverstraw bay was not evident as the study progressed. Also, fish caught in Newburgh Bay tended to be smaller than those caught in Haverstraw Bay. This suggests that either there was poor recruitment from 2002 or 2003 year classes resulting in a reduction of the

smallest size class by fall 2004, or the smallest size classes of fish had not yet migrated down to Haverstraw Bay.

Yearly variation in the downriver migration of early juveniles may complicate population monitoring efforts. Bain et al. (1999) also found concentrations of juvenile Atlantic sturgeon in Haverstraw Bay, but concluded that these were largely age-2 and older fish which had not yet emigrated from the river. Thus, they recommended that relative abundance of fish in Haverstraw Bay not be used as an index of population trends and that sampling should concentrate on age-1 fish during the summer in southern Newburgh Bay. Concentrating on age-1 fish would show year to year variability in recruitment, but as our sampling has shown, sampling in Newburgh Bay would also result in greater variability in CPUE data and a lower chance of being able to detect population trends though time. Using relative abundance as an index of abundance in Haverstraw Bay requires the assumptions that the proportion of juvenile Atlantic sturgeon within a cohort immigrating to Haverstraw Bay is constant each year, and that the proportion of juveniles from a cohort emigrating from the river is constant each year. An advantage of looking at several year classes in a population monitoring effort is that yearly variation in relative abundance due to variability in recruitment of age-1 fish may be dampened and allow for a greater probability of detecting trends for the population as a whole.

Size distributions of juvenile Atlantic sturgeon varied with gill net mesh size, although there was large degree of overlap in size distributions between mesh sizes. The 127 mm stretch mesh tended to catch larger fish, but similar sized fish were also caught in 76 and 102 mm stretch mesh. The morphology of juvenile Atlantic sturgeon (sharply

pointed rostrums, large pectoral spines, and jagged scutes) often resulted in fish being caught by entanglement rather than "gilling". Total numbers of juvenile Atlantic sturgeon caught in 127 and 102 mm stretch mesh were equivalent, but 76 mm stretch mesh tended to catch fewer fish. However, the smallest sized fish (> 375 mm FL) were only caught in 76 mm stretch mesh. If our data is to serve as a baseline for continued monitoring, 76, 102, and 127 mm stretch mesh should be used in future efforts.

The low number of recaptured juvenile Atlantic sturgeon makes generalizations about growth difficult due to confounding factors such as season marked vs. season recaptured and allometric effects on growth. Dovel and Berggen (1983) found juvenile Atlantic sturgeon grew 100 mm or more over the course of a year during the late 1970s. Of the fish which had at least one full year between capture events, absolute growth was greater than 100 mm. Better quantitative analysis of growth can be made as more fish are tagged and recaptured during future monitoring efforts.

RECOMMENDATIONS FOR POPULATION MONITORING

Location

Future population monitoring should focus effort in soft/deep areas of Haverstraw Bay. These areas yielded the most frequent catches of at least one Atlantic sturgeon, which decreases variability in CPUE data. Soft/deep areas also had the highest CPUE and lowest variance on CPUE.

The juvenile Atlantic sturgeon found in Haverstraw Bay likely represent mixed cohorts. The assumptions that must be recognized with using Haverstraw Bay for population monitoring are: (1) the proportion of juvenile Atlantic sturgeon within a

cohort immigrating to Haverstraw Bay is constant each year; and (2) the proportion of juveniles from a cohort emigrating from the river is constant each year.

Season

Sampling should be conducted during the spring of the year, after water temperatures exceed 4°C (approximately March 20). During both spring seasons of our study CPUE dramatically increased in soft/deep areas once this thermal threshold was reached, likely due to increased activity of juvenile Atlantic sturgeon.

Tide

We did not detect any influence of tidal conditions (running vs. slack) on catches of juvenile Atlantic sturgeon in Haverstraw Bay. Therefore, to maximize the amount of effort that may be expended during a working day, nets may be set without concern of tidal conditions.

Mesh sizes

We recommend that 76, 102, and 127 mm stretch mesh sizes be used to effectively capture the size range of juvenile Atlantic sturgeon which may be present. We also recommend that one of each size be set in a "block" patterns as so that each individual net set has the same amount of effort is expended as in this study, thus making the probability of catching a juvenile Atlantic sturgeon, if it is present, equivalent to this study. Our results from soft/deep areas during spring 2005 (after March 20) may then be used as the first year of monitoring.

Sample sizes

Sample size requirements during each spring of monitoring depend on the desired level of change in CPUE to be detected. The recommended sample sizes given in Table

7 may serve as a guide. For example, if a 10% change in CPUE per year is the minimum desired change to be detected in ten years of monitoring (Figure 5), then 14 samples must be taken per spring season to have 80% power or 24 samples must be taken for 95% power (Table 7). To detect the same level of change with sampling occurring every other year, then 22 samples are required for 80% power and 36 samples are required for 95% power.

Another index of abundance which should be monitored through time is the proportion of net sets that result in catches > 0. The underlying assumption when using CPUE as an index of abundance is that CPUE and absolute abundance are directly proportional, which has long been known to not always be the case (Beverton and Holt 1957). Bannerot and Austin (1983) found the square root of the relative frequency of zero CPUE was a less biased index of fish stock abundance than mean CPUE. Analysis of future monitoring data should include both mean CPUE as well as the method proposed by Bannerot and Austin (1983).

ACKNOWLEDGEMENTS

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REFERENCES

ASMFC. 1998a. Atlantic States Marine Fisheries Commission Atlantic sturgeon stock assessment peer review report. ASMFC, Washington, D.C., USA.

ASMFC. 1998b. Atlantic States Marine Fisheries Commission Amendment 1 to the interstate fishery management plan for Atlantic sturgeon. Fishery Management Report No. 31. ASMFC, Washington, D.C., USA.

Bain, M.B. 1997. Atlantic and shortnose sturgeon of the Hudson River: common and divergent life history attributes. Environmental Biology of Fishes 48:347-358.

Bain, M.A., D.L. Peterson, K.K. Arend, and N. Haley. 1999. Atlantic sturgeon population monitoring for the Hudson River Estuary: Sampling Design and Gear Recommendations. Final Study Report to Hudson Rivers Fisheries Unit, Bureau of Marine Resources, NY Department of Environmental Conservation.

Bannerot, S.P. and C.B. Austin. 1983. Using frequency distributions of catch per unit effort to measure fish-stock abundance. Transactions of the American Fisheries Society 122: 608-617.

Bell, R.E., R.D. Flood, S. Carbotte, W.B.F. Ryan, F.O. Nitsche, S. Chilrud, R. Arko, V. Ferrini, A. Slagle, C. Bertinato, M. Turrin. 2006. Hudson River Estuary Program bentic mapping project. Final Report to the Hudson River Estuary Program, New York State Department of Environmental Conservation.

Beverton, R.J.H and S. J. Holt. 1957. On the dynamics of exploited fish populations. Fishery investigations, Series II, Marine Fisheries, Great Britain Ministry of Agriculture, Fisheries and Food 19.

Dovel, W.L. and T.J. Berggren. 1983. Atlantic sturgeon of the Huston estuary, New York. New York Fish and Game Journal 30: 140-172.

Gerrodette, T. 1987. A power analysis for detecting trends. Ecology 68: 1364-1372.

Gerrodette, T. 1993. Trend: software for power analysis of linear regression. Wildlife Society Bulletin 21: 515-516.

Haley, N.J. 1999. Habitat characteristics and resource use patterns of sympatric sturgeons in the Hudson River estuary. M.S. Thesis. University of Massachusetts Amherst, Amherst, MA.

Haley, N.J., J. Boreman, and M. Bain. 1996. Juvenile sturgeon habitat use in the Hudson River. Section VII: 36 pp. *In*: J.R. Waldman, W.C. Nieder, and E.A. Blair (eds.), Final Reports of the Tibor T. Polgar Fellowship Program, 1995. Hudson River Foundation, NY.

Nitsche, F.O., R. Bell, S.M. Carbotte, W.B.F. Ryan, and R. Flood. 2004. Process-related classification of acoustic data from the Hudson River Estuary. Marine Geology 209: 131-145.

Peterson, D.L., M.B. Bain, and N. Haley. 2000. Evidence of declining recruitment of Atlantic sturgeon in the Hudson River. North American Journal of Fisheries Management 20: 231-238.

Smith, T.I.J. 1985. The fishery, biology, and management of Atlantic sturgeon, *Acipenser oxyrinchus*, in North America. Environmental Biology of Fishes 14:61-72.

Van Eenennaam, J.P., S.I. Doroshov, and G.P. Moberg. 1996. Reproductive Conditions of the Atlantic sturgeon (*Acipenser oxyrinchus*) in the Hudson River. Estuaries 19: 769-777.

Table 1: Hypotheses tested and statistical methods used.

Hypothesis	Data Used	Statistical Test
Juvenile Atlantic sturgeon use each habitat stratum equally	Fall 2003 and spring 2004 presence/absence data	Chi-square test; separately for each bay and season
Juvenile Atlantic sturgeon most frequently use soft/deep areas in Haverstraw Bay	Fall 2004, spring 2005, and fall 2005 presence absence data; soft/deep vs. all other strata combined	Chi-square test; separately for each season/year
	Pooled fall and spring presence/absence data; soft/deep vs. all other strata combined	Chi-square test; separately for each season
Juvenile Atlantic sturgeon most frequently use soft/deep areas in Haverstraw Bay during the mid to late spring	Pooled spring 2004 and spring 2005 data; Julian dates ≥ 80; soft/deep vs. all other strata combined	Chi-square test
Juvenile Atlantic sturgeon most frequently use deep areas in Newburgh Bay	Fall 2004 presence/absence data; deep vs. shallow strata	Chi-square test
Presence/absence of juvenile Atlantic sturgeon is equal between slack and running tides	Combined spring and combined fall seasons; soft/deep areas in Haverstraw Bay and deep; deep areas in Newburgh Bay	Chi-square test; separately for each season/bay combination
Presence/absence of juvenile Atlantic sturgeon is equal between parallel and perpendicular net sets	Fall 2005 data from Newburgh Bay; all sets from deep areas	Chi-square test
CPUE is greatest in soft/deep areas of Haverstraw Bay	Fall 2004, spring 2005, and fall 2005 CPUE data; soft/deep vs. all other strata combined	One-tailed Wilcoxon two-sample test; separately for each season/year
	Pooled fall data and pooled spring data across years; soft/deep vs. all other strata combined	One-tailed Wilcoxon two-sample test; separately for each season/year
CPUE is greatest in soft/deep areas of Haverstraw Bay during the mid to late spring	Pooled spring 2004 and spring 2005 data; Julian dates ≥ 80; soft/deep vs. all other strata combined	One-tailed Wilcoxon two-sample test
CPUE is equal between seasons in Haverstraw Bay	CPUE data from only soft/deep areas; pooled seasons across years	Two-tailed Wilcoxon two-sample test
CPUE is correlated with water quality parameters	CPUE and water quality data from soft/deep areas in Haverstraw Bay and deep areas in Newburgh Bay	Spearman rank correlation; separately for each bay/season/year combination and for all seasons and years combined within a bay
Size distribution of juvenile Atlantic sturgeon is equivalent among mesh sizes	Fork length (mm) of all fish captured over the entire study in each mesh size	Median test

Table 2: Presence/absence of juvenile Atlantic sturgeon in the Hudson River (Oct. 2003 - Nov. 2005). Parallel and perpendicular refer to the orientation of nets with respect to the shoreline set in deep water habitat of Newburgh Bay. Fall and spring (combined) refers to data that was pooled across years.

Season	Region	Class	# of Net Sets Present	# of Net Sets Absent	Total Net Sets	Total Fish	%Pres	X^2	*p*
Fall 2003	Haverstraw	Hard/Deep	1	3	4	3	25%	6.65	0.08
		Hard/Shallow	3	8	11	60	27%		
		Soft/Deep	9	5	14	23	64%		
		Soft/Shallow	7	20	27	22	26%		
	Newburgh	Hard/Deep	2	15	17	2	12%	6.60	0.09
		Hard/Shallow	0	6	6	0	0%		
		Soft/Deep	5	13	18	12	28%		
		Soft/Shallow	0	14	14	0	0%		
Spring 2004	Haverstraw	Hard/Deep	4	4	8	8	50%	5.74	0.12
		Hard/Shallow	5	8	13	5	38%		
		Soft/Deep	14	9	23	55	61%		
		Soft/Shallow	9	22	31	26	29%		
	Newburgh	Hard/Deep	0	4	4	0	0%	.	.
		Hard/Shallow	0	1	1	0	0%		
		Soft/Deep	0	3	3	0	0%		
		Soft/Shallow	0	4	4	0	0%		
Fall 2004	Haverstraw	Random	9	23	32	51	28%	9.04	0.00
		Soft/Deep	21	11	32	56	66%		
	Newburgh	Random	0	26	26	0	0%	5.53	0.02
		Deep	5	21	26	7	19%		
Spring2005	Haverstraw	Random	14	22	36	65	39%	11.20	0.00
		Soft/Deep	28	8	36	104	78%		
	Newburgh	Parallel	0	5	5	0	0%	.	.
		Perpendicular	0	5	5	0	0%		
Fall 2005	Haverstraw	Random	7	16	23	34	30%	2.04	0.15
		Soft/Deep	3	20	23	10	13%		
	Newburgh	Parallel	7	12	19	14	37%	0.49	0.49
		Perpendicular	5	14	19	22	26%		
Fall (Combined)	Haverstraw	Random*	27	70	97	170	28%	6.98	<0.01
		Soft/Deep	33	36	69	89	48%		
Spring (Combined)	Haverstraw	Random*	32	56	88	104	36%	17.13	<0.01
		Soft/Deep	42	17	59	159	71%		

*Refers to areas other than soft/deep combined.

Table 3: Tidal influence on presence/absence of juvenile Atlantic sturgeon in the Hudson River (Oct. 2003 - Nov. 2005). Only soft/deep areas in Haverstraw Bay and deep areas in Newburgh Bay were used in this analysis to avoid confounding factors of habitat. Data were pooled across years within a season.

Season	Region	Tide	# of Net Sets Present	# of Net Sets Absent	Total Net Sets	Total Fish	%Pres	X^2	*p*
Fall (Combined)	Haverstraw	Running	20	26	46	46	43%	1.05	0.31
		Slack	13	10	23	43	57%		
	Newburgh	Running	10	36	46	17	22%	0.29	0.59
		Slack	14	39	53	43	26%		
Spring (Combined)	Haverstraw	Running	8	21	29	59	28%	2.30	0.13
		Slack	14	16	30	73	47%		
	Newburgh	Running	0	11	11	0	0%	.	.
		Slack	0	6	6	0	0%		

Table 4: Effect of habitat on CPUE (#/m^2/hr) of juvenile Atlantic sturgeon in Haverstraw Bay. *P*- values are from a one-tailed Wilcoxon two-sample test.

Season	Stratum	N	Mean	Median	St. Dev.	Min.	Max.	C.V.	*p*
Fall 2004	Random	32	0.002	0.000	0.003	0.000	0.013	2.090	0.02
	Soft/Deep	32	0.002	0.001	0.002	0.000	0.008	1.246	
Spring 2005	Random	36	0.002	0.000	0.004	0.000	0.018	2.332	<0.01
	Soft/Deep	36	0.003	0.002	0.003	0.000	0.015	1.108	
Fall 2005	Random	21	0.001	0.000	0.003	0.000	0.011	2.366	0.10
	Soft/Deep	25	0.000	0.000	0.001	0.000	0.004	2.722	
Pooled Data*									
Fall	Random	95	0.002	0.000	0.004	0.000	0.027	2.503	0.02
	Soft/Deep	71	0.001	0.000	0.002	0.000	0.008	1.519	
Spring	Random	88	0.001	0.000	0.003	0.000	0.018	2.479	<0.01
	Soft/Deep	59	0.003	0.002	0.003	0.000	0.015	1.204	

*Data were pooled by season across years. Strata other than soft/deep were classified as "random".

Table 5: Spearman rank correlations of CPUE and water quality parameters. Data from spring seasons were omitted for Newburgh Bay because no Atlantic sturgeon were captured.

Region	Season		Temp.	Sp. Cond.	Salinity	D.O.	pH
Haverstraw	Fall 2003	$r_{Spearman}$	0.05	-0.42	-0.60	0.08	0.08
		p	0.87	0.20	0.03	0.81	0.81
		n	14	11	13	12	12
	Spring 2004	$r_{Spearman}$	0.34	-0.15	-0.18	0.04	.
		p	0.12	0.54	0.42	0.87	.
		n	22	20	21	20	
	Fall 2004	$r_{Spearman}$	-0.07	0.23	0.24	-0.11	-0.08
		p	0.72	0.20	0.18	0.57	0.68
		n	32	32	32	32	32
	Spring 2005	$r_{Spearman}$	0.24	0.01	0.03	-0.32	0.15
		p	0.15	0.95	0.87	0.09	0.45
		n	36	29	29	29	29
	Fall 2005	$r_{Spearman}$	-0.08	-0.32	-0.37	0.24	-0.04
		p	0.71	0.13	0.09	0.27	0.85
		n	23	23	23	23	23
	Overall	$r_{Spearman}$	-0.03	-0.05	-0.06	0.14	0.11
		p	0.73	0.58	0.53	0.14	0.30
		n	125	115	118	96	97
Newburgh	Fall 2003	$r_{Spearman}$	0.19	0.17	-0.10	0.32	-0.22
		p	0.31	0.40	0.62	0.09	0.24
		n	31	28	29	29	29
	Fall 2004	$r_{Spearman}$	-0.05	-0.09	-0.17	0.02	-0.17
		p	0.81	0.68	0.43	0.94	0.40
		n	26	23	23	24	26
	Fall 2005	$r_{Spearman}$	0.61	0.58	0.56	-0.50	0.52
		p	<0.01	<0.01	<0.01	<0.01	<0.01
		n	37	37	37	37	37
	Overall	$r_{Spearman}$	0.33	0.30	0.20	-0.17	0.12
		p	<0.01	<0.01	0.07	0.11	0.25
		n	94	88	89	91	92

Table 6: Recaptured Atlantic and shortnose sturgeon.

						Fork Length (mm)		Weight (kg)		Sp. Growth Rate		
Species	**PIT**	**Carlin**	**Date Tagged**	**Date Recap.**	**Days**	**tagged**	**recap.**	**tagged**	**recap.**	**FL (mm/d)**	**Weight (g/d)**	**Comments**
Atlantic	4310647D06 (46182D6303)	16086	10/23/03	10/19/04	362	424	552	0.53	-1	0.000729		lost old PIT, old PIT = 4310647D06
Atlantic	4310514A15	16089	10/30/03	10/7/05	708	553	714	1.15	2.94	0.000361	0.0013258	
Atlantic	431061430B	16155	11/3/03	11/4/04	367	452	592	0.61	1.36	0.000735	0.0021847	
Atlantic	454A0C3914	16579	4/20/04	11/22/04	216	460	571	0.66	1.3	0.001001	0.0031383	
Atlantic	4549336D49 (454B435105)	16582	4/20/04	10/20/04	183	486	587	0.79	1.4	0.001032	0.0031267	Two different PIT numbers for same carlin. Possibley PIT tagged twice.
Atlantic	454A000C0B	16657	4/22/04	10/25/04	186	458	624	1.32	1.22	0.001663	-0.000424	
Atlantic	454B5C3D67	16663	4/22/04	3/23/05	335	396	520	0.37	0.98	0.000813	0.0029076	
Atlantic	45494C0773	16681	4/27/04	10/7/04	163	405	549	0.75	1.19	0.001866	0.0028321	
Atlantic	460D65257C	16939	10/25/04	4/18/05	175	558	578	0.56	1.38	0.000201	0.0051537	
Atlantic	460E431340	16971	11/4/04	11/22/04	18	550	550	1.19	1.12	0	-0.003368	
Atlantic	461621240D	30496	4/18/05	11/3/05	199	633	715	1.95	2.68	0.000612	0.0015979	
Atlantic	435F642D1D	30358	12/4/03	4/27/05	510	535	670	1.15	2.22	0.000441	0.0012897	New Carlin tag, did not have one applied on first capture.
Atlantic	436008372C	30521	12/4/03	10/6/05	672	561	747	1.25	3.3	0.000426	0.0014446	New Carlin tag, no Carlin tagged on first capture, took spine sample from right pectoral fin.
Shortnose	460D561F7B	16888	10/19/04	11/22/04	34	680	678	2.8	2.82	-8.66E-05	0.0002093	

Table 6: *Continued*

Species	PIT	Carlin	Date Tagged	Date Recap.	Days	Fork Length (mm) tagged	Fork Length (mm) recap.	Weight (kg) tagged	Weight (kg) recap.	Sp. Growth Rate FL (mm/d)	Sp. Growth Rate Weight (g/d)	Comments
Shortnose	2270520341	16546	12/5/95	4/7/04	3046	610	597		1.62	-7.07E-06		No Carlin tag, New Carlin applied, originally tagged by Cornell in Esopus Meadows.
Shortnose	220222761D	30734	4/3/95	11/8/05	3872	640	688	2.74	3.33	1.87E-05	5.037E-05	No Carlin tag, New Carlin applied, originally tagged by Cornell in Esopus Meadows.
Atlantic	423B370E61	16728		11/9/04			952					Hatchery release from September 2004 Haverstraw Bay County Park stocking.
Atlantic	467D2D362F	30724		11/4/05			622					Remnants of a carlin tag were present, no PIT tag present, scar from spine removed, spine was taken from right side and new tags applied
Atlantic	470A795E31	30733		11/08/05			1060					Left pelvic fin removed, large fish = possible 1994 hatchery release from NEFC

Table 7. Recommended sample size requirements (i.e. number of net sets per year) to detect a trend in CPUE of juvenile Atlantic sturgeon in soft/deep areas of Haverstraw Bay during the spring (after March 20).

			Rate of CPUE increase (%/yr.)										
	Power	Years of monitoring	5.0%	7.5%	10.0%	15.0%	20.0%	25.0%	30.0%	35.0%	40.0%	45.0%	50.0%
Annual Sampling	80%	5	416	212	129	62	41	26	20	16	13	11	9
		10	47	20	14	7	5	4	3	2	2	2	2
		15	15	7	5	3	2	2	1	1	1	1	1
		20	7	3	3	2	1	1	1	1	1	1	1
	95%	5	1,154	416	289	129	73	53	36	29	24	20	17
		10	86	36	24	13	9	6	5	4	3	3	3
		15	24	11	8	5	3	2	2	2	2	1	1
		20	11	6	4	2	2	1	1	1	1	1	1

	Power	Years of monitoring	5.0%	7.5%	10.0%	15.0%	20.0%	25.0%	30.0%	35.0%	40.0%	45.0%	50.0%
Biennial Sampling	80	5	2,596	1154	1,154	416	289	212	163	129	104	86	73
		10	73	29	22	11	7	5	4	4	3	3	2
		15	26	13	9	5	3	3	2	2	2	2	1
		20	11	5	4	2	2	1	1	1	1	1	1
	95%	5	10,384	2596	2,596	1,154	649	416	416	289	212	212	163
		10	129	53	36	20	13	9	7	6	5	4	4
		15	47	22	16	9	6	4	3	3	3	2	2
		20	19	9	7	4	3	2	2	2	1	1	1

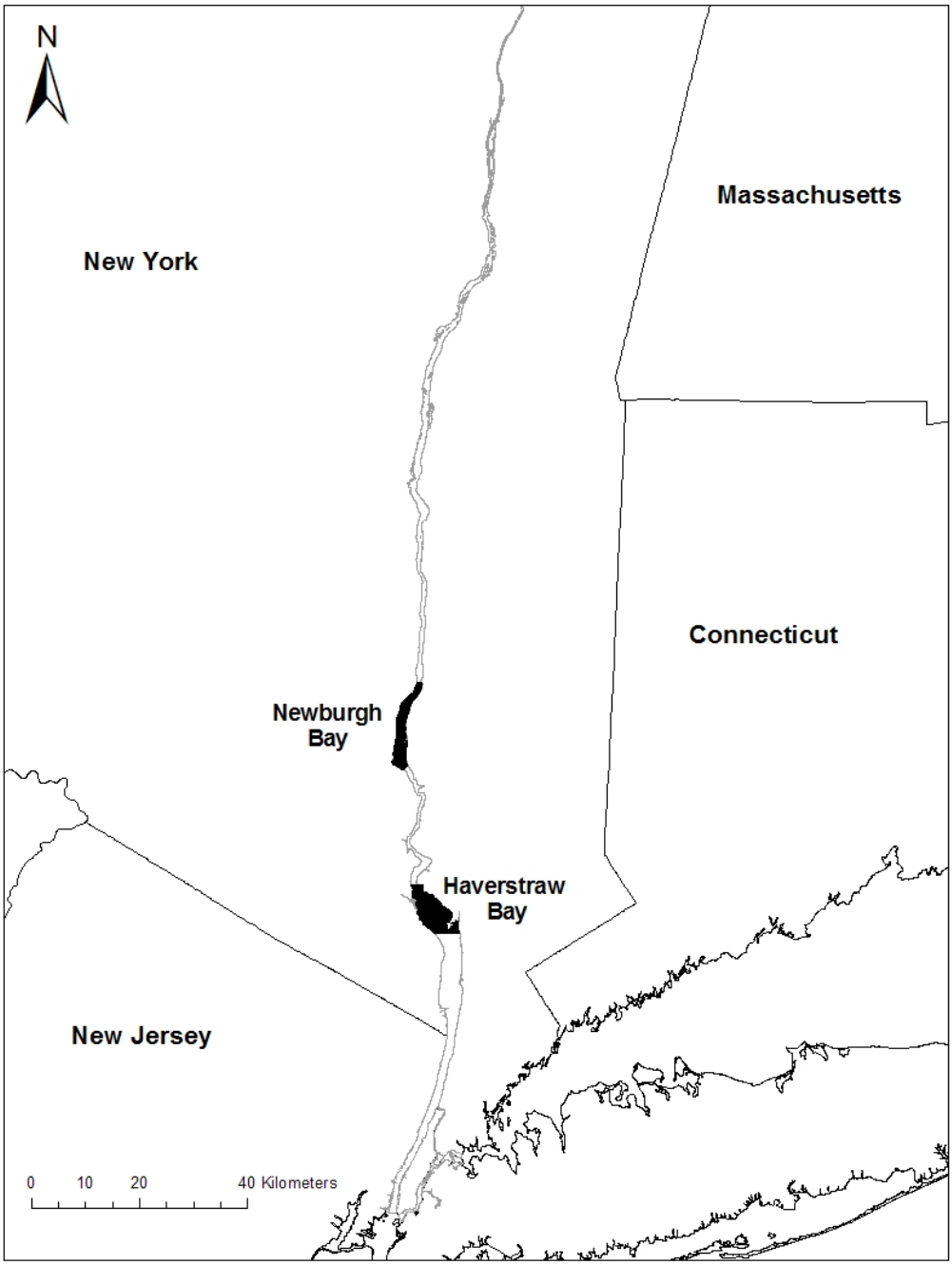


Figure 1: Location of Newbugh and Haverstraw Bays in the Hudson River, NY.

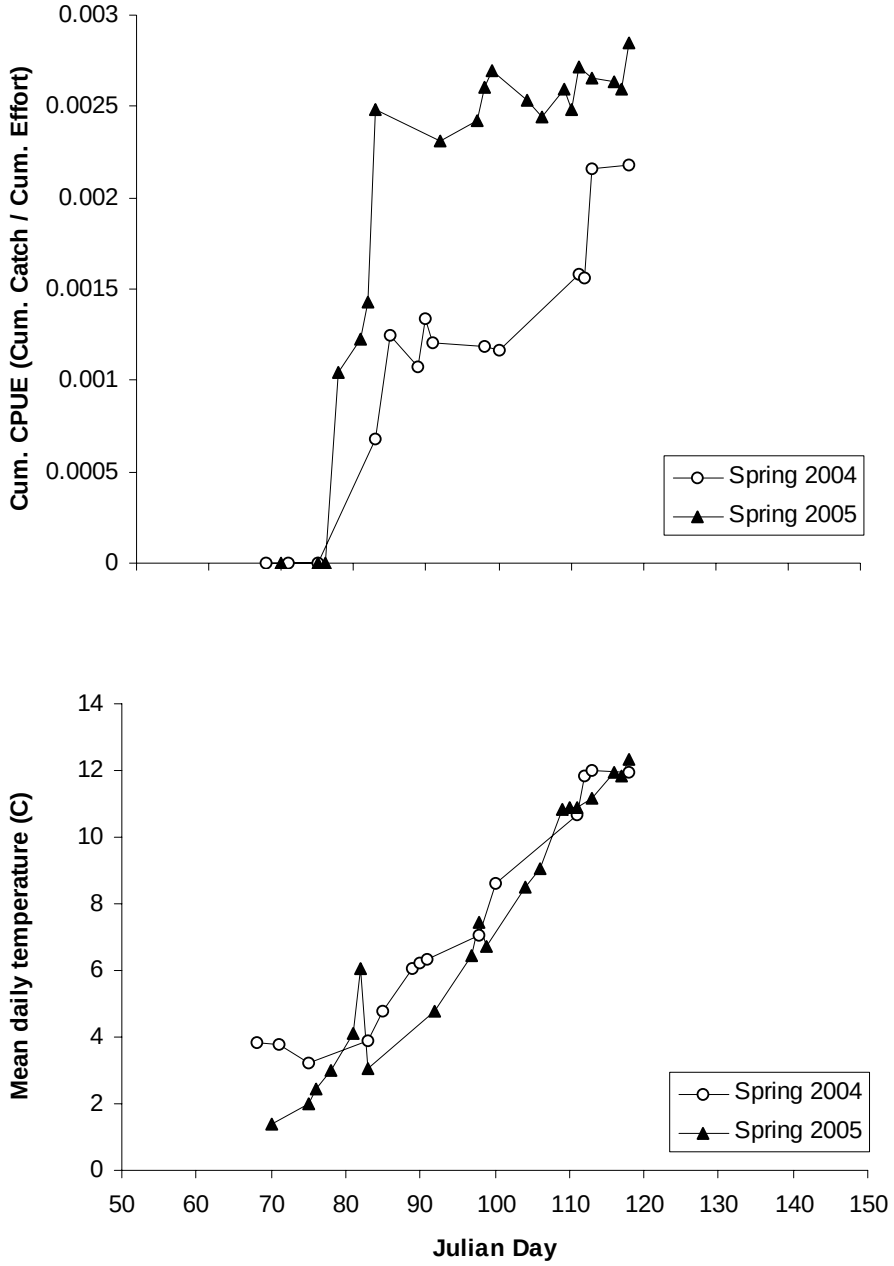


Figure 2: Cumulative CPUE and mean daily water temperature from soft/deep areas of Haverstraw Bay during spring 2004 and 2005. As water temperatures began to exceed 4°C during each spring on approximately Julian day 80 (March 20), CPUE increased sharply.

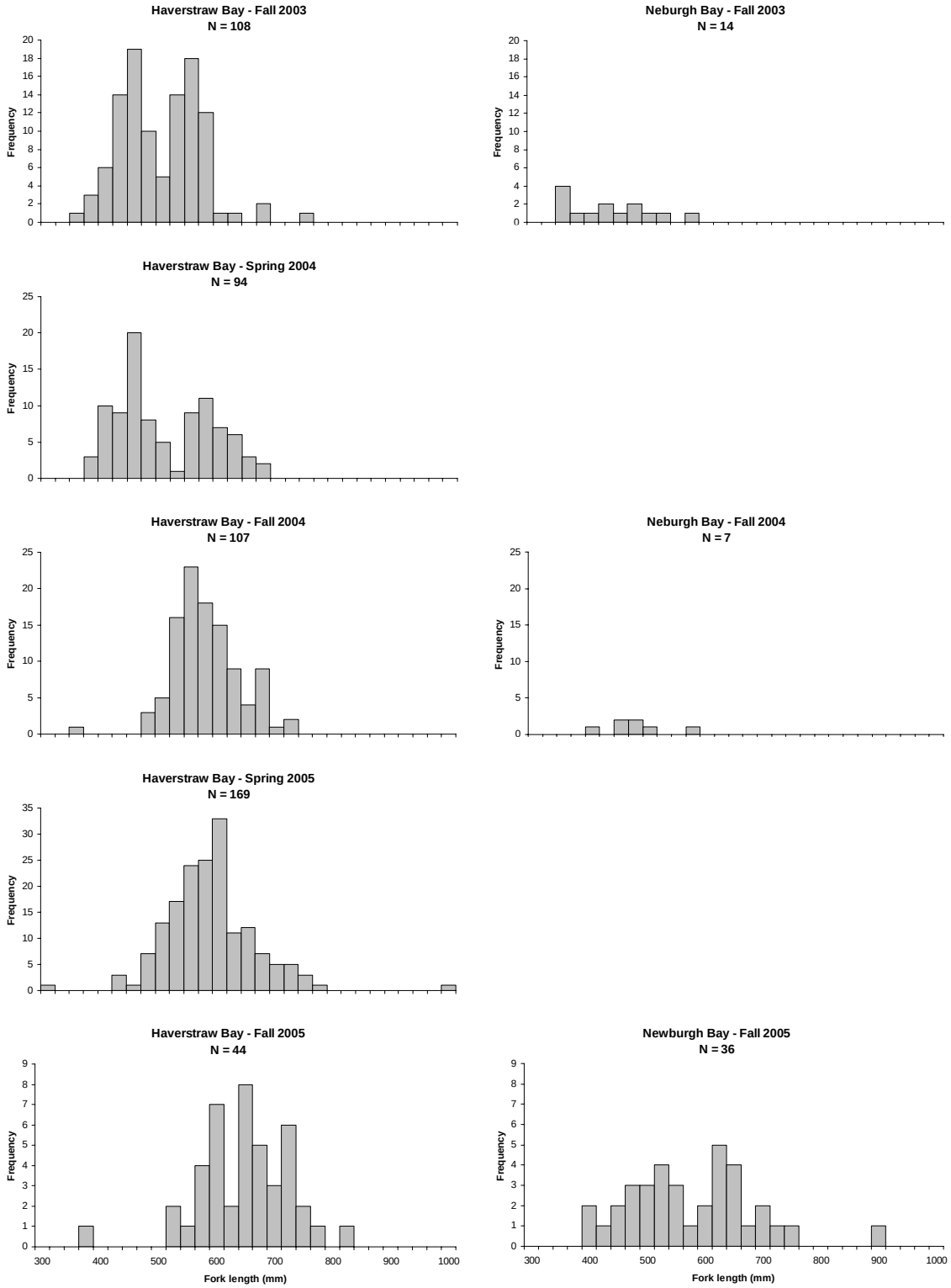


Figure 3: Length frequency histograms of juvenile Atlantic sturgeon for Haverstraw and Newburgh Bays of the Hudson River, NY (October 2003 – November 2005).

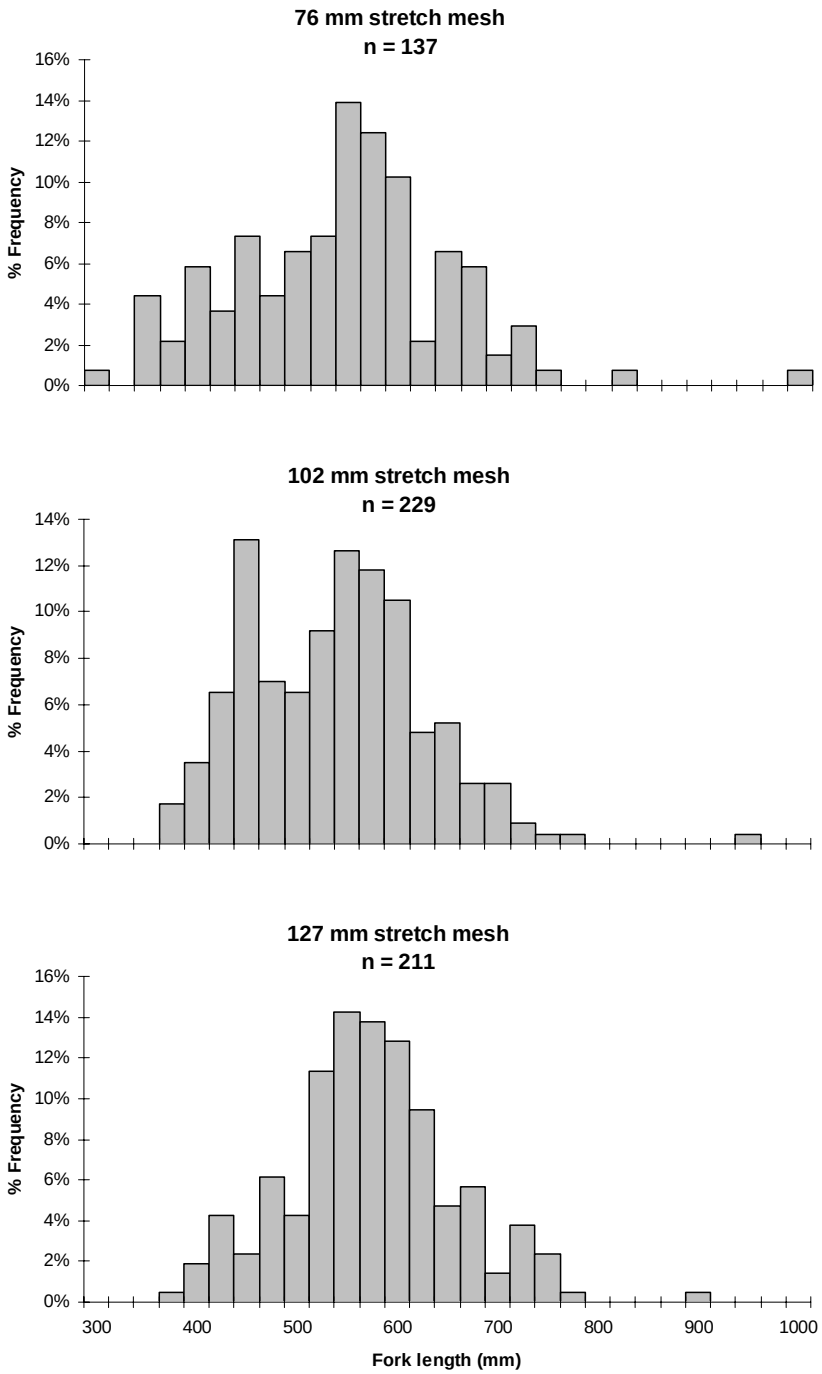


Figure 4: Length frequency histograms of juvenile Atlantic sturgeon caught in the Hudson River (October 2003 – November 2005) for various mesh sizes. A median test showed 127 mm stretch mesh caught significantly larger fish than did the 76 or 102 mm stretch mesh ($p = 0.02$).

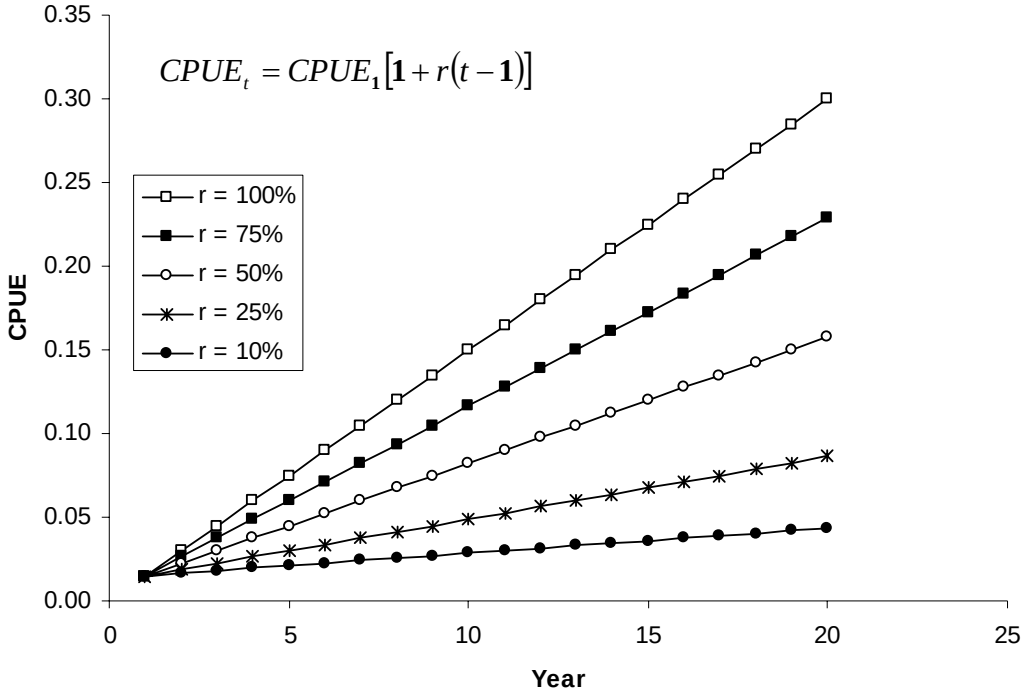
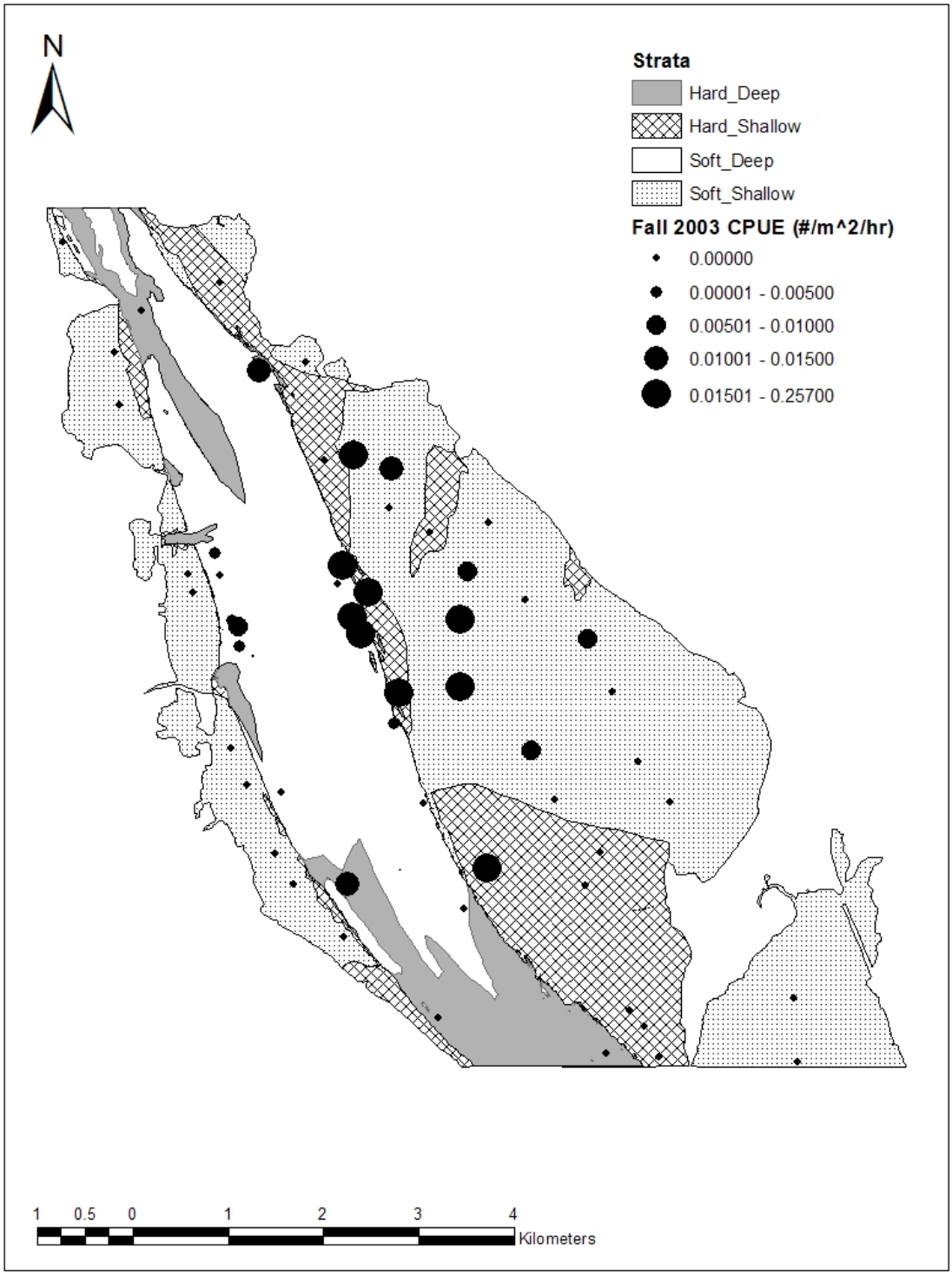


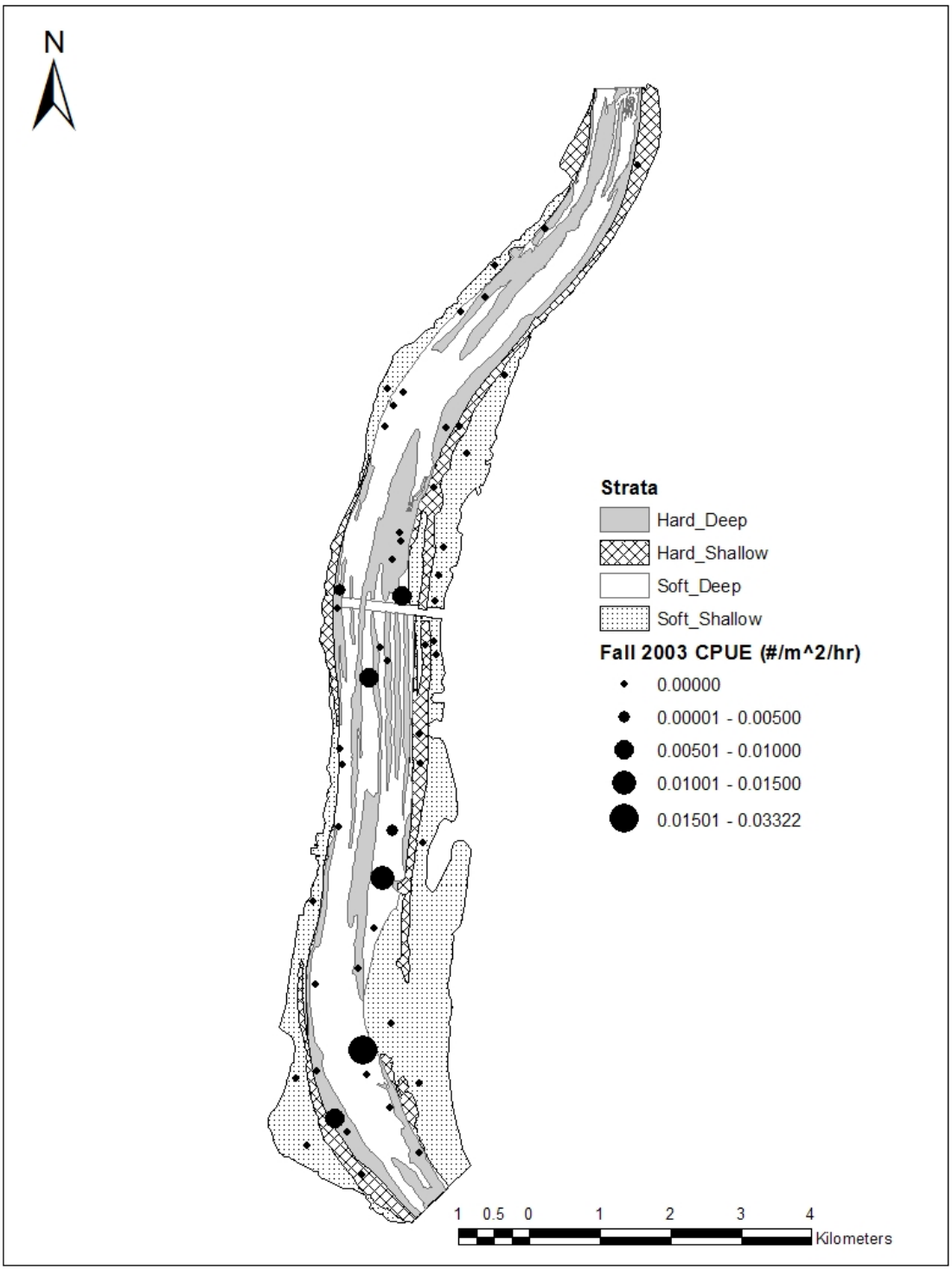
Figure 5: Examples of the potential change in mean CPUE over time for increasing rates of increase (*r*).

APPENDIX

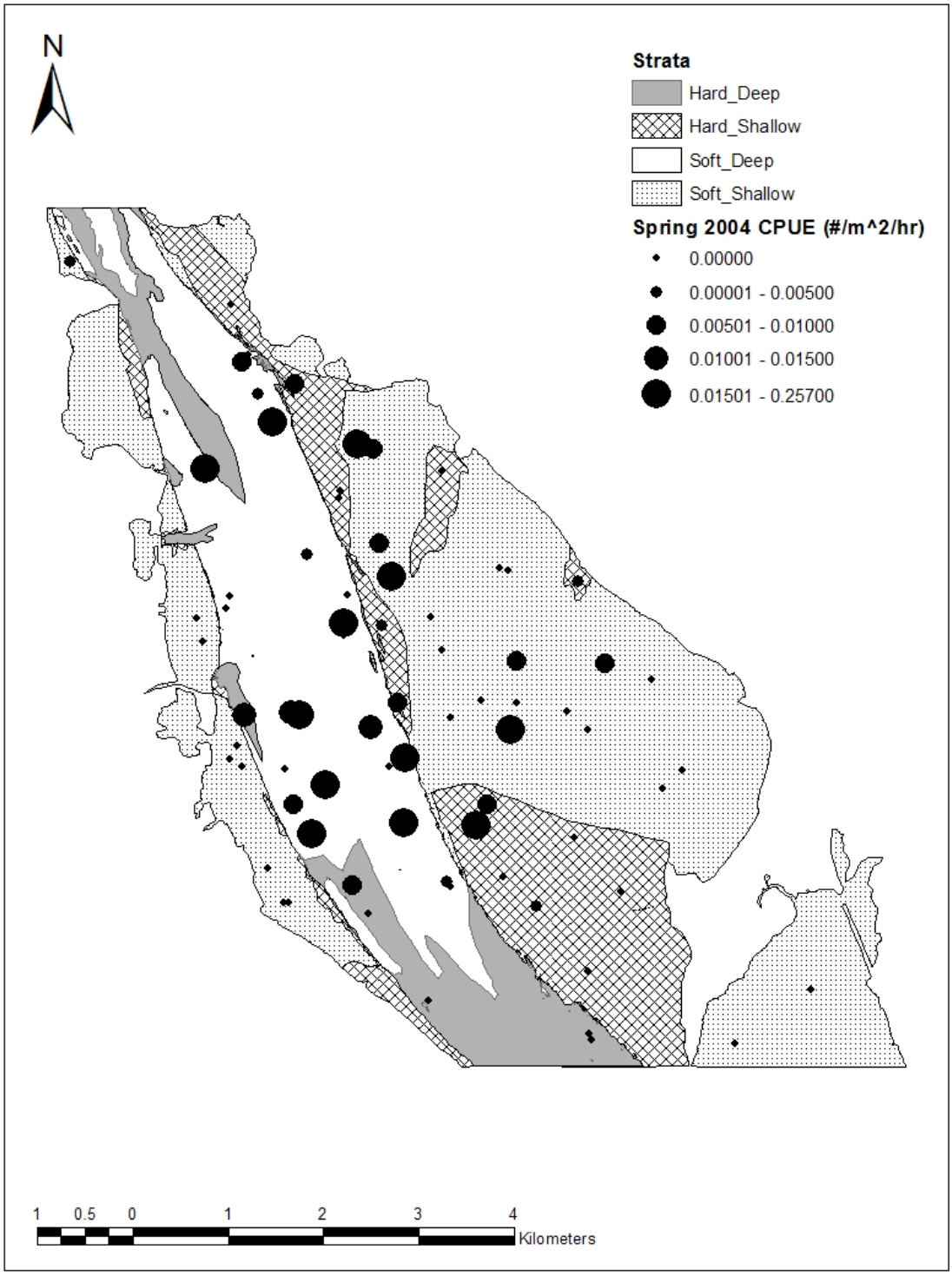
Maps of Juvenile Atlantic Sturgeon Catches



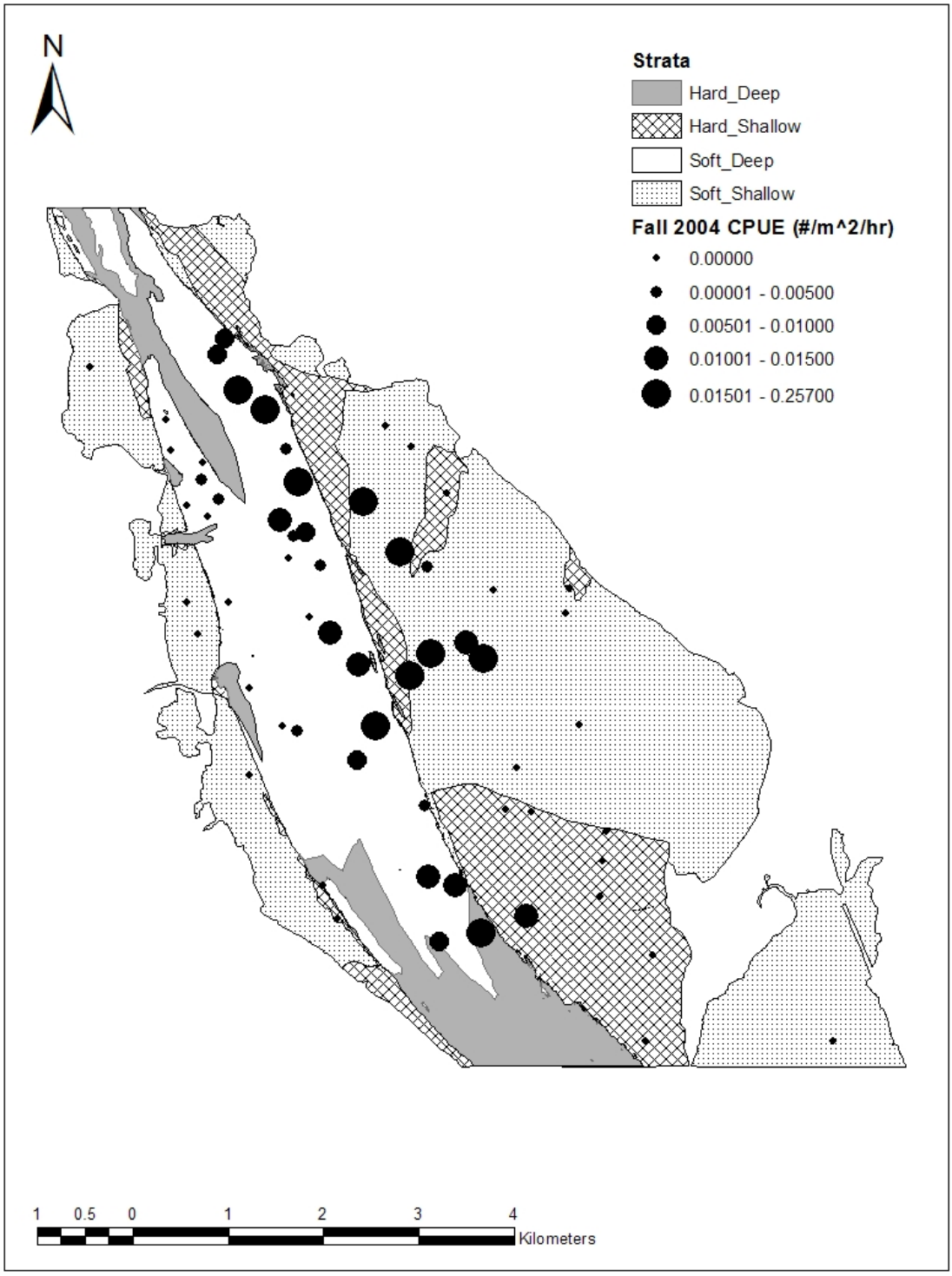
Map 1: Catches of juvenile Atlantic sturgeon in Haverstraw Bay of the Hudson River, NY (Oct. – Nov. 2003).



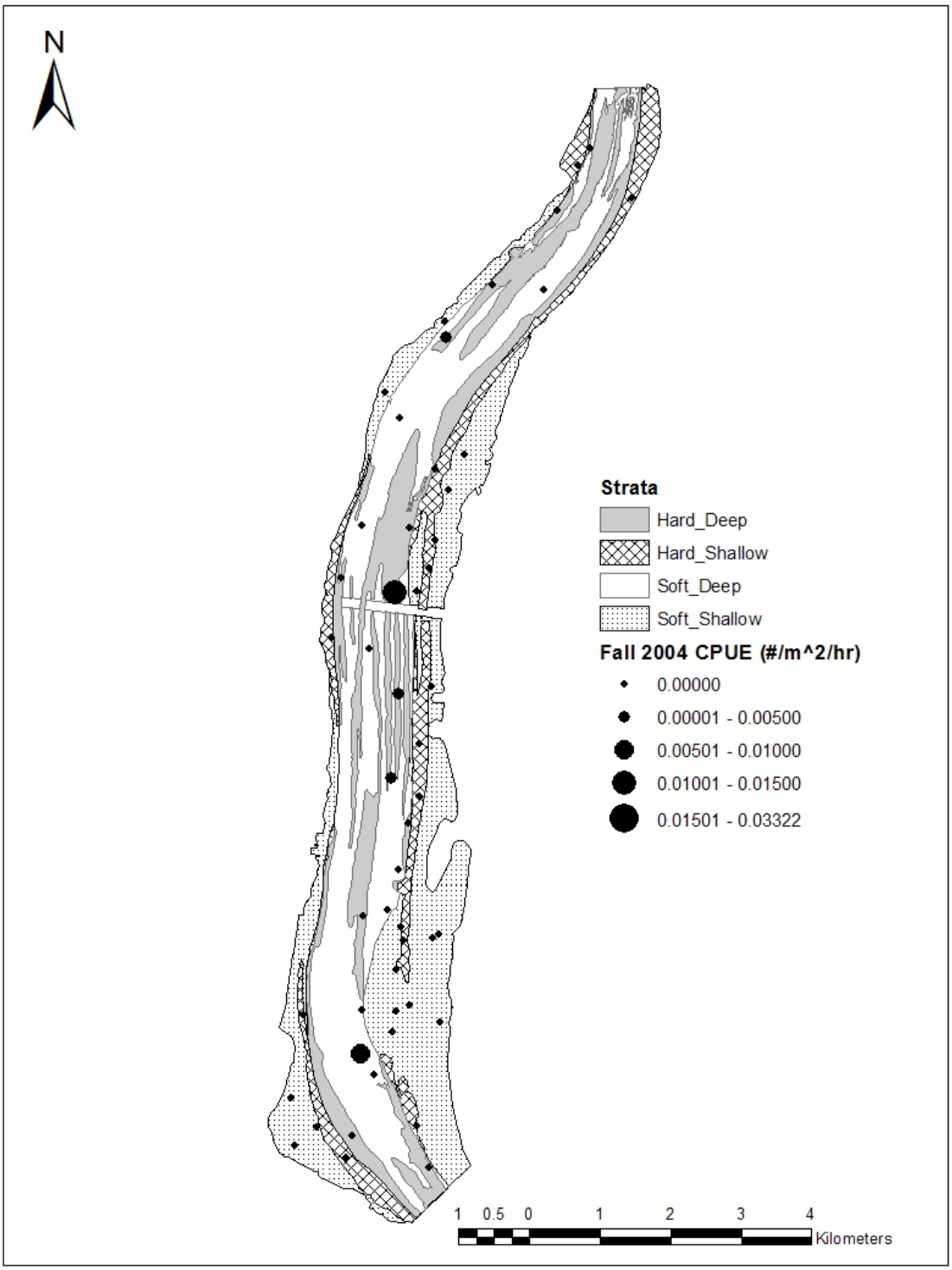
Map 2: Catches of juvenile Atlantic sturgeon in Newburgh Bay of the Hudson River, NY (Oct. – Nov. 2003).



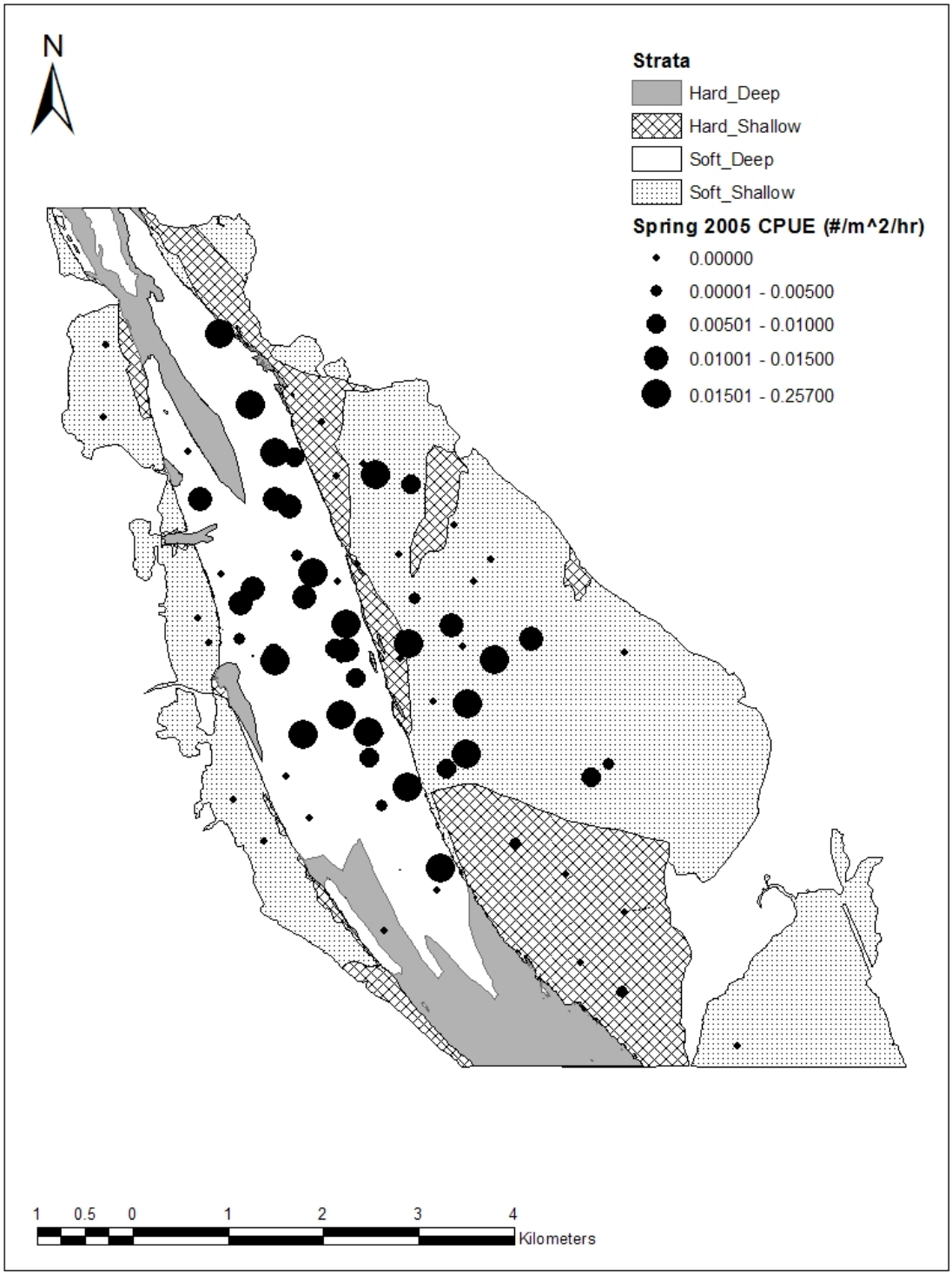
Map 3: Catches of juvenile Atlantic sturgeon in Haverstraw Bay of the Hudson River, NY (March – April 2004).



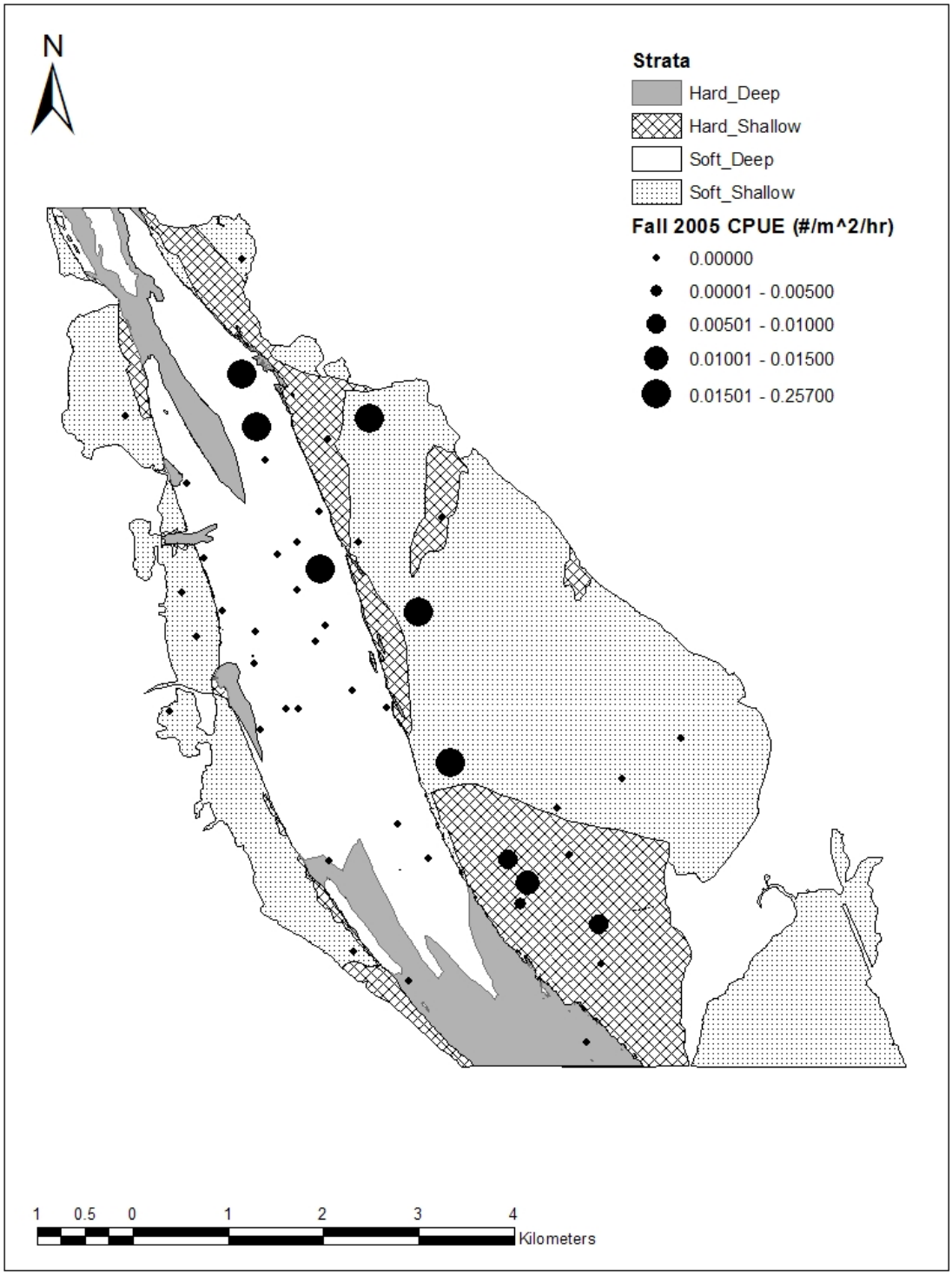
Map 4: Catches of juvenile Atlantic sturgeon in Haverstraw Bay of the Hudson River, NY (Oct. – Nov. 2004).



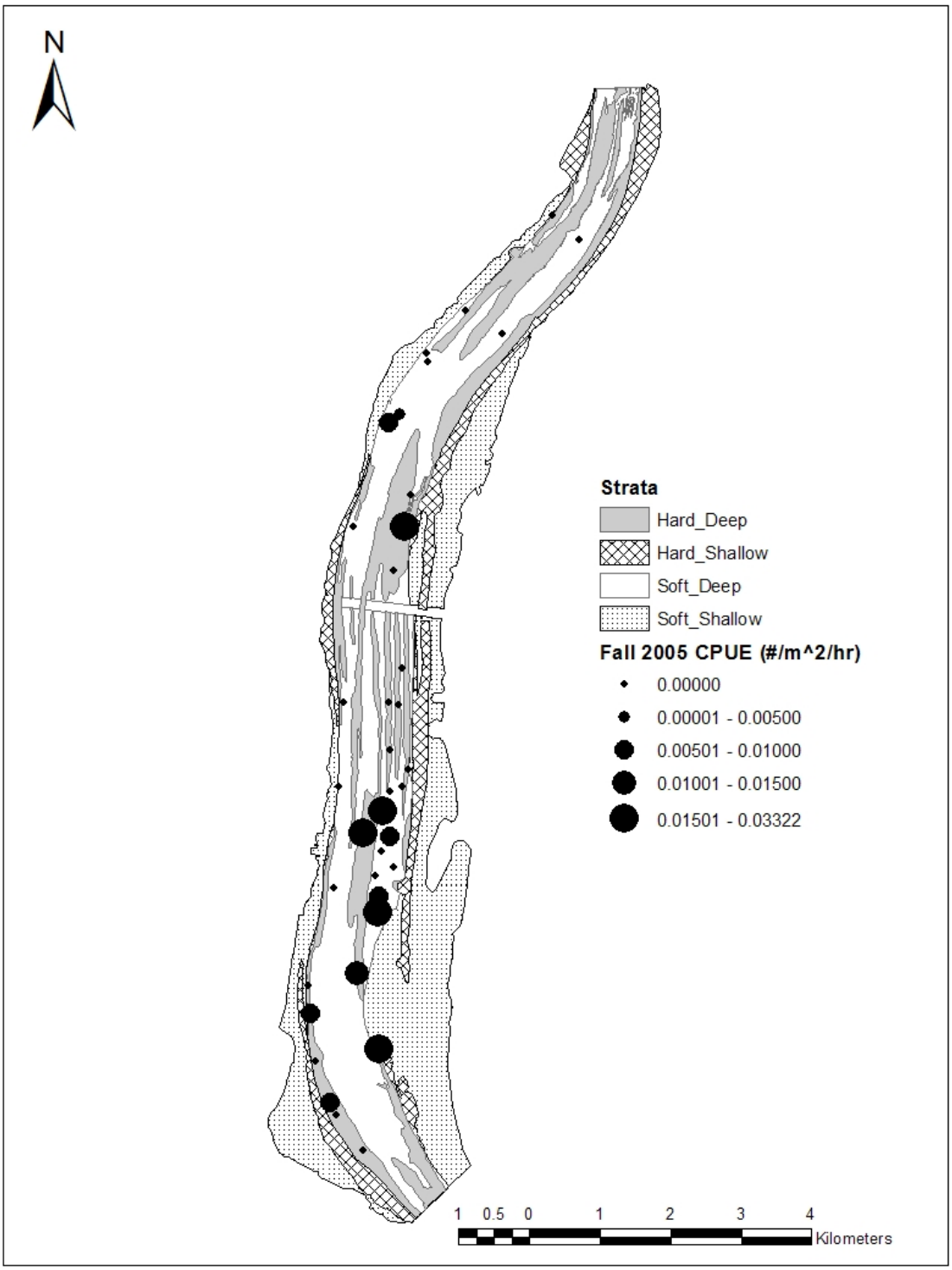
Map 5: Catches of juvenile Atlantic sturgeon in Newburgh Bay of the Hudson River, NY (Oct. – Nov. 2004).



Map 6: Catches of juvenile Atlantic sturgeon in Haverstraw Bay of the Hudson River, NY (March – April 2005).



Map 7: Catches of juvenile Atlantic sturgeon in Haverstraw Bay of the Hudson River, NY (Oct. – Nov. 2005).



Map 8: Catches of juvenile Atlantic sturgeon in Newburgh Bay of the Hudson River, NY (Oct. – Nov. 2005).