New Jersey Department of Environmental Protection
Division of Fish and Wildlife
Marine Fisheries Administration
Bureau of Shellfisheries

DETERMINATION OF ABUNDANCE AND DISTRIBUTION OF BAY SCALLOPS (*ARGOPECTEN IRRADIANS*) IN LITTLE EGG HARBOR BAY.

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ABSTRACT

To determine the distribution and abundance of *Argopecten irradians* in Little Egg Harbor Bay, the New Jersey Bureau of Shellfisheries sampled 157 stations between the Route 72 causeway and Little Egg Harbor Inlet. All fieldwork was conducted between 6 November 2006 and 29 November 2006. Total *Argopecten* abundance (all sizes) was estimated at 46,773 individual scallops, a decline of 91% from a survey of the same area in fall 2005. The decline in abundance, on a per-station basis, was significant ($V = 352$, $p = 9.46\times10^{-05}$). The adult population (age 1+) abundance was estimated at between 16 and 22 bushels, assuming 700 and 500 *Argopecten* bushel^{-1}, respectively. This represents a decline of approximately 75% from 2005's estimate. *Argopecten* abundances at individual stations ranged from 0.000 to 0.004 *Argopecten* foot^{-2}, or from 0.0 to 194 *Argopecten* acre^{-1}. In Little Egg Harbor Bay, most *Argopecten* occur in the shallow central and eastern portions of the bay. Marginally significant associations existed between *Argopecten* and live *Zostera marina* (eelgrass) and *Ruppia maritima* (Widgeon grass) ($\chi^2 = 3.122$, $df = 1$, $p = 0.0948$). We found a marginally significant increase in the proportion of stations containing versus not containing SAV between 2005 and 2006 ($d = -1.8766$, $p = 0.0686$). Two dominant age classes emerged from our data: a juvenile age class with a mean shell height of 19.0 mm (SD = 5.6 mm), and an adult age class with a mean shell height of 40.0 mm (n = 1 $\therefore$ SD = NA). No *Argopecten* boxes (i.e., paired valves) were collected during the course of our survey. Over 75% of the *Argopecten* collected were age 0, suggesting pre-survey harvest of adults or larval transport from adult stocks outside of Little Egg Harbor Bay. Other explanations are proffered. The 2006 *Argopecten* survey of Little Egg Harbor Bay represents a positive step towards the management of New Jersey's *Argopecten* resource. Review of historical reported landings data for New Jersey along with studies documenting protracted *Argopecten* population recoveries demonstrate the delicate nature of *Argopecten* population dynamics. Before establishing a directed fishery in New Jersey, subsequent surveys are needed as well as a better understanding of *Argopecten* ecology in New Jersey.

INTRODUCTION

The bay scallop, *Argopecten irradians*, is an ecologically and economically important bivalve inhabiting coastal marine embayments where seagrasses are generally abundant (Gutsell 1930). Landings reported to the National Marine Fisheries Service (NMFS) indicate that this species was commercially harvested in New Jersey intermittently between 1956 and 1974 (Table 1) [1]. During this time, landings of 2.0 million pounds (mean/SD = 106,237 / 129,932 lbs) valued at $1.13 million (mean/SD = $59,717 / $72,236) were reported. Reports of abundant or even existent *Argopecten* were largely absent during the mid-1970s through the early 2000s. The reasons for *Argopecten*'s decline or absence are not known, though unsustainable levels of harvest or environmental factors (Gobler et al. 2005, Tettelbach and Wenczel 1993) might reasonably have contributed.

Beginning in the early-2000s the New Jersey Bureau of Shellfisheries began receiving periodic verbal reports that *Argopecten* was again becoming locally abundant in New Jersey coastal estuaries between Sea Isle City (Cape May County) and Barnegat Bay (Ocean County). These intermittent verbal reports combined with interest expressed by shellfishermen at Atlantic Coast Shellfisheries Council meetings were the impetus for the Bureau of Shellfisheries

[1] *Argopecten* regulations were allowed to sunset in 1981 due to the lack of fishery participation brought on by the virtual disappearance of *Argopecten* after 1974 (Table 1).

conducting the first quantitative, comprehensive *Argopecten* survey of Little Egg Harbor Bay (LEHB) in the fall of 2005.

The goal of the present study is to build upon the first survey by quantitatively re-sampling all of LEHB. Concurrent annual samples will provide an opportunity to move beyond baseline data and make progress towards assessing the viability of fishery development. Two consecutive years of data will also provide unique insights into the ecology of *Argopecten* in New Jersey, heretofore scantily available. Finally, this second year of data will also provide valuable information necessary to move the survey towards a stratified random design, should resources be available for continuation of the survey.

MATERIALS AND METHODS

Study Site

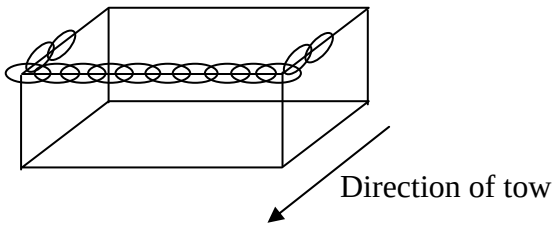
All fieldwork was conducted in Little Egg Harbor Bay, Ocean County, New Jersey (Figure 1). Little Egg Harbor Bay is one of three shallow microtidal bays that comprise the Barnegat Bay – Little Egg Harbor estuarine system (Barnegat Bay Estuary Program 1999). Seawater enters the system through the Point Pleasant Canal, Barnegat Inlet and Little Egg Inlet (Barnegat Bay Estuary Program 1999).

Sampling: Design, Equipment, and Protocol

Quantitative sampling was conducted from 6 November 2006 to 29 November 2006 in Little Egg Harbor Bay. We sampled all stations using a 20′ Privateer outboard vessel powered by a 115 hp outboard motor. All samples were collected with a single 1.00′ × 2.03′ × 0.83′ (D×W×H) scallop dredge, lined with 0.5″ × 0.5″ mesh wire. The anterior ventral dredge margin had a 4-pound weight (approximately 3/8″ diameter galvanized chain, approximately 17.5′ long) attached (Figure 2, below). Qualitative surveys conducted prior to the actual survey indicated that this weight enhanced the gear's ability to fish smoothly through submerged aquatic vegetation and algae.

We towed the dredge using a 5/8″ diameter laid nylon line connected from the dredge bridle to a cleat located on the port stern. We used a towline length-to-depth ratio of 3:1 (mean/SD = 3.1:1 / 0.17:1), although, in several instances it was not possible to maintain this ratio because of changes in bathymetry. We recorded water depth from a Garmin Fishfinder 120 and determined the towline length accordingly.

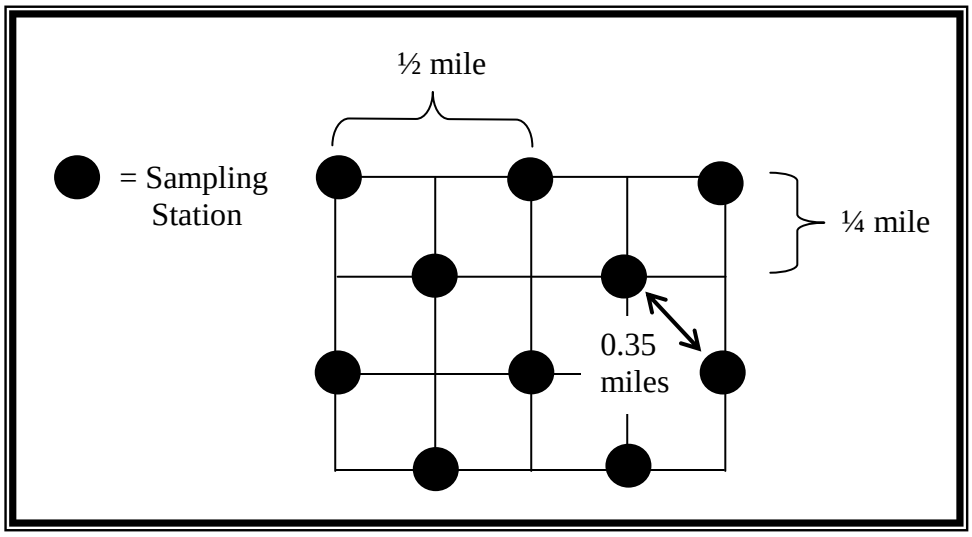
FIG. 2. Schematic of dredge equipped with weight.



We chose to replicate the experimental design used in our previous survey of LEHB (see Celestino 2006b) to make the two-year comparison as strong as possible. Specifically, we used a systematic sampling design. Station locations were established at ½-mile intervals offset along east-west transects ¼-mile apart such that stations on adjacent transects were approximately 0.35

miles apart (see Figure 3, below). Thirty-seven stations sampled in 2005 were not sampled in 2006 due to water depths and supplemental data collected during the 2005 survey (e.g., stations where the dredge was dumped due to clogging with mud). All stations were located using a Northstar 951X Differential GPS receiver chart plotter.

FIG. 3. Schematic of systematic sampling design grid.



After station position was established, a single one-minute dredge tow was conducted at each station. In instances where it was not possible to tow for the full minute, the duration of the tow was recorded. Each tow was made into or against the prevailing wind or tide to help maintain as straight a towpath as possible. We recorded geographic coordinates (latitude and longitude) at the start, at the approximate midpoint (i.e., after approximately 30 seconds), and at the end of the tow.

After completing the one-minute tow, the vessel was stopped (held as stationary as possible) and the dredge was retrieved either by hand or 12 V electric capstan windlass. The catch was sorted onboard the vessel. All live *Argopecten* and paired *Argopecten* valves (boxes) collected in each tow were counted and measured (shell height; maximum distance from the umbo to the ventral margin) to the nearest whole millimeter using vernier calipers. We noted the presence or absence of a one-year growth ring, the presence of other animal and plant species collected in the dredge (e.g., submerged aquatic vegetation and *Argopecten* predators), and we also made qualitative descriptions of the substrate and vegetation (e.g., vascular plants and algae, live or dead, sparse or abundant). We developed distribution charts of *Argopecten* using ArcView v3.2a (2000).

We collected physico-chemical data at the first and last stations sampled in a day. We collected water samples with a Kemmerer water sampler for subsequent analysis of dissolved oxygen, salinity and pH at the New Jersey Division of Fish and Wildlife's Nacote Creek Research Laboratory, Port Republic, New Jersey. Water temperatures (surface and bottom) were recorded from a mercury thermometer in the field. Dissolved oxygen was determined by Winkler titration. Salinities were determined by a hand-held refractometer and pH readings were obtained using colorimetric visual analyses against known standards (Taylor® slide comparator).

We compared water quality measurements between the present and previous surveys using Wilcoxon's rank sum test (RDCT 2006). We used the station mean (surface and bottom),

where available, as the response variable to reduce spatial correlation to the maximum extent possible.

Population Size/Age Structure

Two height-percent-frequency distribution graphs were constructed by appropriately grouping all *Argopecten* heights measured in the bay. Heights were combined into one- as well as five-millimeter groupings to help illustrate possible multiple spawning events and composite age classes, respectively. Low *Argopecten* abundances precluded preparation of height-percent-frequency distributions at all individual stations (all n < 100). For comparative purposes, plots simultaneously depict 2005 and 2006 data.

Argopecten Distribution and Abundance Estimation

Argopecten abundance indices for each station are expressed in terms of number of *Argopecten* feet^{-2}. This index was calculated by dividing the total number of all live *Argopecten* by the total distance towed × 2.03 (the width of the dredge). We calculated the distance towed[#] as the distance from the start of the tow to the midpoint + the distance from the midpoint to the end of the tow. This method helps reduce the effect of any towpath curvature on the estimation of abundance.

To estimate total *Argopecten* abundance in Little Egg Harbor Bay, station location information was brought into ArcView v3.2a. Adjacent stations where *Argopecten* was colleted were grouped together and enclosed in polygons. These areas (feet^2 calculated in ArcView) were summed and multiplied by the mean *Argopecten* abundance calculated by summing all individual abundance indices greater than zero and dividing by that number of stations (Eq. 1). This method was chosen to maintain consistency with the method used for confidence interval estimation (see below). Our approach implicitly assumes that one tow was representative of a larger area (*i.e.*, an entire sampling cell; see Figure 3). Unfortunately, there are no data to either support or refute this assumption – limitations on time and funding precluded an investigation. However, to minimize this source of estimation error, sampling frequency was increased to the maximum extent practicable (see Figure 3).

$$\text{Total } \textit{Argopecten} \text{ Abundance} = \frac{\Sigma\ (\textit{Argopecten} \text{ abund. indices} > 0)}{N\ (\text{for } \textit{Argopecten} \text{ abund. indices} > 0)} \times \left(\begin{array}{c} \text{Total area (feet}^2\text{) where} \\ \textit{Argopecten} \text{ abund. indices} > 0 \end{array} \right) \quad \text{Eq. 1}$$

With this estimate of total *Argopecten* abundance in Little Egg Harbor Bay, we then estimated the number of age 0 and age 1+ *Argopecten* by multiplying the total *Argopecten* abundance in Little Egg Harbor Bay by the fraction of age 0 and age 1+ *Argopecten* collected in the survey, respectively. We define age 0 *Argopecten* as those *Argopecten* collected without the presence of a one-year growth ring. Conversely, age 1+ *Argopecten* are those with a one-year growth ring. Accordingly,

$$\text{Total abundance of Age 0 } \textit{Argopecten} = \frac{\text{Total abund.}^{*} \text{ of Age 0 } \textit{Argopecten} \text{ collected}}{\text{Total abund. of all } \textit{Argopecten} \text{ collected}} \times \text{total } \textit{Argopecten} \text{ abundance calculated from equation 1}$$

[#] Distance towed = 3963.189 * acos(sin(lat1) * sin(lat2) + cos(lat1) * cos(lat2) * cos(lon2 - lon1)).

[*] Total abund. = total *Argopecten* abundance standardized to number foot^{-2}. This method differs from that used in Celestino (2006b) where we used total number of *Argopecten*.

Analogously,

$$\text{Total abundance of Age 1+ } \textit{Argopecten} = \frac{\text{Total abund.}^{*} \text{ of Age 1+ } \textit{Argopecten} \text{ collected}}{\text{Total abund. of all } \textit{Argopecten} \text{ collected}} \times \text{total } \textit{Argopecten} \text{ abundance calculated from equation 1}$$

We provide estimates of total and age 1+ *Argopecten* abundance as the number of individual *Argopecten* as well as bushels of *Argopecten*. No data are known to the author definitively equating the number of *Argopecten* to bushels[@]. Hence, estimates of bushels are provided assuming 500, 600, and 700 *Argopecten* per bushel based on comparisons with other estuarine shellfish species.

A 95% confidence interval around the point estimate of abundance was generated via Monte Carlo simulation. We used 4,999 simulations. Resampling for each simulation was limited to stations where *Argopecten* were actually collected (i.e., *Argopecten* abundance > 0.0 feet^{-2}). We believe this is the most ecologically realistic method that should then give rise to the most realistic abundance estimates used in generating the confidence interval. Alternate methods of confidence interval generation require either predicting *Argopecten* abundances or homogenization of the study area, both deemed undesirable.

Finally, we compared *Argopecten* abundances between the 2005 and 2006 surveys of Little Egg Harbor Bay via Wilcoxon's signed rank test for paired replicates.

Mortality

We did not collect any empty paired valves (boxes) in the present study. If we had collected boxes, an index of natural *Argopecten* mortality would have been determined at each station. This index would have been based upon the percentage of empty paired valves (boxes) in the entire sample of paired valves and live *Argopecten*: Mortality = {[(no. of boxes at station i) ÷ (no. of boxes at station i + no. of live *Argopecten* at station i)] × 100%}, for i = 1,…,157. Our mortality index is independent of age and size of *Argopecten*.

Recruitment

For the purpose of this study, we define recruitment as the percentage of *Argopecten* entering the fishery after approximately one year of life. To estimate annual recruitment, (*Argopecten* collected without the presence of a one-year growth ring) represented a single year class and would thus be expected to be recruited into the fishery within the coming year (assuming 100% survivorship). The recruitment index per station was calculated as: {[(no. of *Argopecten* collected not displaying a growth ring at station i) ÷ (total no. of *Argopecten* collected at station i)] × 100%}, for i = 1,…,157. We also report the total number of age 0 *Argopecten* estimated to be present in the bay (see *Argopecten Distribution and Abundance Estimation*, above).

RESULTS

Description of Study Site

All sampling locations were characterized as having salinities between 21‰ and 27‰ ($\bar{x}$ = 23.9‰; SD = 1.7‰), water temperatures between 9° and 15°C ($\bar{x}$ = 11.1°C; SD = 2.2°C),

[*] Total abund. = total *Argopecten* abundance standardized to number foot^{-2}. This method differs from that used in Celestino (2006b) where we used total number of *Argopecten*.

[@] Conversion factors would likely change at least annually, and be location-specific.

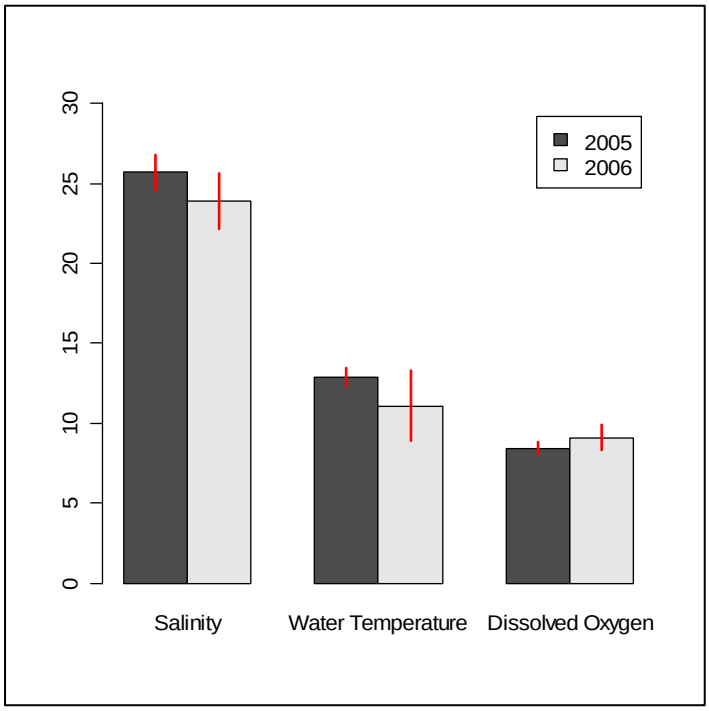
and dissolved oxygen levels between 7.5 mg/l and 10.6 mg/l ($\bar{x}$ = 9.1 mg/l; SD = 0.8 mg/l). Salinity, temperature, and DO were relatively evenly distributed throughout the bay (note low SD's relative to mean). Physico-chemical data are provided in Table 2, and presented spatially in Figure 4.

During the respective sampling periods, salinity was higher in 2005 than in 2006 (W = 98, p = 0.0123), water temperatures were warmer in 2005 than in 2006 (W = 96, p = 0.0179), and dissolved oxygen was lower in 2005 than in 2006 (W = 18.5, p = 0.0068) (Table 3 and Figure 5, below) (see Celestino 2006b for values from 2005 survey).

TABLE 3. Summary statistics of water quality parameters from 2005 and 2006 [mean (standard deviation)] *Argopecten* surveys of Little Egg Harbor Bay.

	2005	2006
Salinity (‰)	25.7 (1.1)	23.9 (1.7)
Water Temperature (°C)	12.9 (0.6)	11.1 (2.2)
Dissolved Oxygen (mg/l)	8.4 (0.4)	9.1 (0.8)

FIGURE 5. Summary statistics of water quality parameters from 2005 and 2006 *Argopecten* surveys of Little Egg Harbor Bay. The mean +/- 1 standard deviation is plotted. Salinity was measured in parts per thousand, water temperature in degrees Celsius, and dissolved oxygen in milligrams per liter.

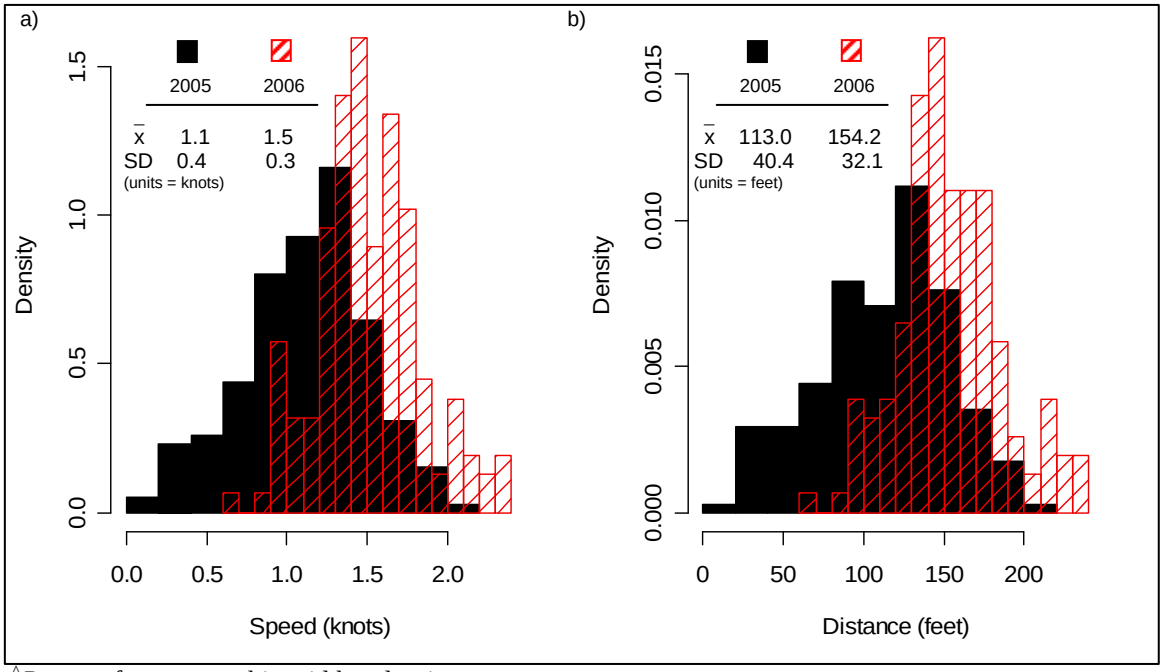


***Argopecten* Abundance and Distribution**

Station location (for station midpoint), *Argopecten* abundance, mean length, percent age 0s (the measure of recruitment for purposes of this study), as well as station and tow statistics for each station are presented in Table 4. The locations of the 157 stations sampled are presented in Figure 6.

The total *Argopecten* (all sizes) resource in Little Egg Harbor Bay is estimated at 46,773 individual scallops (Table 5). Stock estimates by age class are also presented in Table 5. Sampling tow statistics are provided in Figure 7, below. Post-hoc Wilcoxon signed rank tests for paired replicates indicated that both vessel speed (V = 1,817.5, $p = 1.562\times10^{-14}$) and tow distance (V = 1,258, $p = 1.533\times10^{-13}$) differed significantly between the two surveys[2].

FIGURE 7. Histograms[^] and comparative statistics of a) dredge tow speeds and b) tow distances between the 2005 and 2006 *Argopecten* surveys of Little Egg Harbor Bay.



[^] Percent-frequency = bin width × density

Figure 8 depicts the distribution and abundance of *Argopecten* in Little Egg Harbor Bay in 2006. Figure 9 depicts *Argopecten* abundances in Little Egg Harbor Bay in fall 2005, spring 2006, and fall 2006 (see Celestino 2006a for complete details of the spring 2006 samples; only data from the State dredge was used for Figure 9). In the present survey, *Argopecten* abundances ranged from 0.0000 to 0.0045 *Argopecten* foot^{-2}. These values may not possess immediate intuitive appeal and so can alternately be expressed as 0.0 to 194 *Argopecten* acre^{-1}.

Wilcoxon's signed rank test for paired replicates indicted a significant decline in *Argopecten* abundances between 2005 and 2006 (V = 352, $p = 9.46\times10^{-05}$).

[2] As previously noted, for the present survey, we eliminated deep water stations where our dredge clogged with mud in 2005. This explains, in part, some of the differences in tow statistics.

Population Size/Age Structure

To illustrate *Argopecten* age/size structure in Little Egg Harbor Bay, height percent-frequency distribution graphs are presented in Figure 10. Plots are provided with one- and five-millimeter groupings. Summary composite (all *Argopecten* measured) shell height statistics are provided in Table 6.

TABLE 6. Summary composite shell height statistics for *Argopecten* collected in Little Egg Harbor Bay in 2005 and 2006.

	2005	2006
n =	31	4
$\bar{x}$ =	22.2 mm	24.8 mm
SD =	12.0 mm	12.4 mm

Recruitment

Recruitment indices exhibited binomial variability among stations in 2006, being either 0.0% or 100% with a bay-wide mean of 75.0% (Table 4).

Mortality

The bay-wide average *Argopecten* mortality for Little Egg Harbor Bay was 0.0%. No boxes were collected in the present survey.

DISCUSSION AND CONCLUSIONS

The estimated standing stock of *Argopecten* in Little Egg Harbor Bay in 2006 is 46,773 individual scallops. This represents a decline of over 91% from 2005's estimate of 528,538 individual scallops. The decline of *Argopecten* abundance (on a per-station basis) between the two surveys was significant ($V = 352$, $p = 9.46\times10^{-05}$).

Mean *Argopecten* abundance among all stations sampled (bay wide average) was 0.0001 (SD = 0.0006) *Argopecten* foot^{-2}, a decline of approximately 86% from 2005's survey. Mean *Argopecten* abundance among stations where *Argopecten* were collected was 0.0035 (SD = 0.0007) *Argopecten* foot^{-2}, or 152.5 *Argopecten* acre^{-1}, a decline of 34.0% from 2005.

Age 0 *Argopecten* constitute the majority of the population (by number, ~77% in the present survey and ~92% in 2005). There are several possible explanations for the preponderance of juveniles despite the relatively low number of adults. First, a significant fraction of the adult population may have been harvested prior to our survey. Current marine enforcement policy allows harvest of *Argopecten* via hand implements, and preliminary reported[3] NMFS landings indicate that all landings in 2006 occurred prior to our survey. Some fraction of the collected juveniles may have been imported into Little Egg Harbor Bay from adult stocks outside of the bay (e.g., Manahawkin or Barnegat Bay), but in New Jersey waters [(see Bologna et al. (2001)]. Bologna et al. (2001) reports a larval duration of 10-14 days making larval transport a reasonable hypothesis. Alternately, perhaps few resident adults are all that is necessary to account for the observed juvenile abundances. Finally, the adult population may simply be what Bologna et al. (2001, pg. 94) characterize as "resident, albeit cryptic."

It logically follows that approximately 23% of 2006's total estimated abundance consists of *Argopecten* age 1 or older (Table 5). This equates with between 16 and 22 bushels of adult

[3] Note: there are no reporting requirements, and thus the reported landings almost certainly underestimate true landings.

Argopecten, assuming 700 and 500 scallops bushel^{-1}, respectively. In contrast, approximately 8% of 2005's total abundance were age 1 or older (Table 5), equating with 63 to 88 bushels of adult *Argopecten*, assuming 700 and 500 scallops bushel^{-1}, respectively.

A decline of 75% in the point estimate of adult abundance (see Table 5) between the two surveys is within the loss expected to occur due to natural mortality. In fact, the instantaneous natural mortality estimate for *Argopecten* is M=1.5 (i.e., 78% annual loss based on a 2 year life span; Hoenig 1983). If 100% of the decline could be solely attributed to natural mortality, and further, we assume that natural mortality should yield a loss of 78.0%, that would suggest that approximately 1,342 of 2005's Age 0 *Argopecten* (≈ 0.3%) recruited to the fishery in 2006 (i.e., 99.7% of 2005's Age 0 *Argopecten* did not recruit). Revised reported landings to the National Marine Fisheries Service indicate 0 pounds of *Argopecten* were landed 2005, and preliminary reported landings indicate 465 pounds of *Argopecten* (statewide) were landed in 2006 (all landings occurred prior to our survey).

Accounting for any natural mortality is problematic, as we did not collect any *Argopecten* boxes in our survey. This might be due to high *Argopecten* shell disarticulation rates or the inefficiency of our dredge to collect and/or retain boxes. We had difficulty in our previous survey of Little Egg Harbor Bay (Celestino 2006b) accounting for natural mortality where we collected only three boxes, equating with a bay-wide estimate of 41,744 total boxes.

Explanations for the observed decline in abundance, apart from natural mortality, might include variable dredge efficiency at various vessel speeds[4]. Figure 11 depicts *Argopecten* abundances greater than zero as a function of average vessel speed for the fall 2005 (Celestino 2006b), spring 2006 (Celestino 2006a), and fall 2006 surveys of Little Egg Harbor Bay combined. Due to the presence of a single very large catch during the spring 2006 survey, a suspected outlier data point, we also present a composite plot without the suspected outlier (Figure 11b). A linear regression line has been added to the plots to illustrate a general linear relationship (R^2 = 0.0319, p = 0.2580 with the outlier, and R^2 = 0.1303, p = 0.0204 without the outlier). In fact, the plots suggest three separate linear relationships in the data, all of the form, decreasing abundance with increasing speed. Fitting a cubic smoothing spline to the data shows that the relationship is not strictly linear. A unimodal and bimodal relationship appear when the suspected outlier is included (Figure 11a) and excluded (Figure 11b), respectively. A general parabolic model has intuitive appeal, as we expect abundance to approach zero as speed approaches zero. Additionally, hydrodynamic (e.g., a wall of water) or physical (e.g., a dredge that clogs after traveling too long a distance) forces might prevent or limit collection of *Argopecten* beyond some optimal speed (or distance). The relationship between speed and abundance is complex, but with the outlier catch removed, a simple linear relationship accounts for almost 15% of the variation in *Argopecten* abundances across all sampling periods, suggesting that the relationship is somehow important in explaining *Argopecten* abundances.

Analyzing the speed-*Argopecten* abundance relationship for each sampling separately supports a linear and/or unimodal relationship. Figure 12 (a and b) depicts *Argopecten* abundances greater than zero as a function of average vessel speed for the fall 2005 (Celestino 2006b), spring 2006 (Celestino 2006a), and fall 2006 surveys of Little Egg Harbor Bay, individually. Here again, we fit linear regression and cubic smoothing splines to the data. The linear relationship between speed and abundance describes 15% (p = 0.0539) of the fall 2005

[4] Distance traveled may be the more relevant metric, but as speed is nearly perfectly correlated with distance in our dataset (Pearson correlation coefficient = 0.9955, $p < 0.0001$), and we can only directly control vessel speed (and thereby indirectly distance), we limit our discussion to the relationship between *Argopecten* abundance and speed.

data and **97%** ($p = 0.0129$) of the fall 2006 data. The spring 2006 data has the weakest linear relationship accounting for 9% of the variation with the outlier included and 0.8% of the variation with the outlier removed. Not surprisingly, the spring 2006 data appear to have the strongest unimodal relationship of the time series (see cubic smoothing spline for spring 2006 in Figures 12 a and b). Future exploratory work is needed to elucidate the relationship between *Argopecten* abundance and speed.

Notwithstanding the discussion above, dramatic changes in *Argopecten* abundance are not uncommon. Table 1 suggests that extraordinary fluctuations in abundance are the historical norm. Population recovery after population collapse, as inferred from reported NMFS landings data, ranges from one to over 30 years. This slow rebuilding period is similar to that reported from North Carolina, where recovery rates from harvest and red tide ranged from 5 to 12 years (Peterson and Summerson 1992). Examination of National Marine Fishery Service landings data for other East Coast states (e.g., New York, Rhode Island) shows that a pattern of erratic landings, population crashes, and slow (or non-existent) recoveries, is common for *Argopecten*. Peterson and Summerson (1992) concluded that the slow recovery of *Argopecten irradians concentricus* in North Carolina might be due to recruitment limitation at low population sizes. The potential for recruitment limitation combined with the short life span of *Argopecten* calls for special care when managing *Argopecten*. The unpredictable nature of algal blooms (e.g., *Aurococcus anophagefferens*), with their concomitant direct and indirect impacts on *Argopecten* survival (Tettelbach and Wenczel 1993, Gobler et al. 2005), adds another layer of complexity to *Argopecten* management.

With one exception, the sedge islands in southern Little Egg Harbor Bay, *Argopecten* were collected within the range of sites they were collected in the 2005 survey [i.e., the shallow ($\bar{x}$ = 5.2′ in 2005, 5.4′ in 2006) central and eastern portions of Little Egg Harbor Bay between Ship Bottom and Marshelder Islands] (Figure 9). Additionally, similar to 2005's survey where we found an association between SAV and *Argopecten* ($\chi^2 = 49.832$, $df = 1$, $p = 1.70 \times 10^{-12}$, see Celestino 2006b), there is evidence of a marginal association between SAV and *Argopecten* ($\chi^2 = 3.122$, $df = 1$, $p = 0.0948$; Figure 13) in the present survey. Finally, there was a marginally significant change (increase) in the proportion of stations containing versus not containing SAV between 2005 and 2006 ($d = -1.8766$, $p = 0.0686$), among the stations sampled in both years (Figures 14 and 15).

FIG. 13. Table of *Argopecten-Zostera* associations from the 2006 survey of Little Egg Harbor Bay.

		Zostera	
		Present	Absent
Argopecten	Present	3	1
	Absent	50	103

As in 2005, two dominant age classes emerge from the height-percent-frequency plots in Figure 10. The mean shell height of the age 0's is 19.0 mm (SD = 5.6 mm). See Table 7, below, for a comparison with 2005's data. We could not find data on juvenile growth rates for New Jersey. Bologna et al. (2001) found evidence of *Argopecten* spawning in Little Egg Harbor Bay from late spring, through late summer and early fall (September-October). These results are similar to Tettelbach et al. (1999), who found evidence of spawning peaks during June to July and again in late August to September in New York. Tettelbach et al. (1999) also report evidence of a November spawn.

The mean shell height of the age 1+'s is 40.0 mm (n = 1 ∴ SD = NA). See Table 7, below, for a comparison with data from 2005.

FIG. 14. Table of *Argopecten* occurrences from the 2005 and 2006 surveys of Little Egg Harbor Bay.

		Zostera (2006)	
		Present	Absent
Zostera (2005)	Present	37	7
	Absent	16	97

TABLE 7. Summary composite shell height statistics by age class for *Argopecten* collected in Little Egg Harbor Bay in 2005 and 2006.

	Age 0		Age 1+	
	2005	2006	2005	2006
Mean	18.8	19.0	53.3	42.0
SD	5.4	5.6	12.5	NA (n = 1)
Range	9 – 31	13 – 24	39 – 62	42

The 2005 and 2006 *Argopecten* surveys of Little Egg Harbor Bay represent positive steps towards the management of New Jersey's *Argopecten* resource. Relatively low adult abundances, uncertainties regarding the ultimate and proximate factors controlling the abundance and distribution of *Argopecten*, combined with a ~75% decline in adult abundance despite no official fishery combine to complicate fishery development. These factors certainly prompt caution. Review of historical reported landings data for New Jersey along with studies documenting protracted *Argopecten* population recoveries demonstrates the delicate nature of *Argopecten* population dynamics. Before establishing a directed fishery in New Jersey, subsequent surveys are needed as well as a better understanding of *Argopecten* ecology in New Jersey.

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Table 1. *Argopecten* landings from all New Jersey State waters reported by the National Marine Fisheries Service.

Year	Pounds	Dollars
1956	314,100	287,300
1957	71,600	39,785
1958	93,500	50,546
1959	4,400	3,162
1960	0	0
1961	70,800	66,494
1962	364,700	129,438
1963	273,900	112,172
1964	376,300	154,911
1965	95,500	45,000
1966	174,600	85,314
1967	85,500	40,292
1968	16,800	24,216
1969	0	0
1970	0	0
1971	0	0
1972	0	0
1973	60,600	71,628
1974	16,200	24,372
1975 *	0	0
2003 *	0	0
2004	379	2,970
2005	0	0
2006 **	465	8,570
Total (1956-2006)	2,019,344	1,146,170

Summary statistics (1956-1974, inclusive)$^{\Delta}$

Minimum	0	0
Maximum	376,300	287,300
Mean	106,237	59,717
SD	129,932	72,236

Δ Statistics for this time series are for ilustrative purposes only.

* No landings reported between 1975 and 2003.

** Preliminary landings.

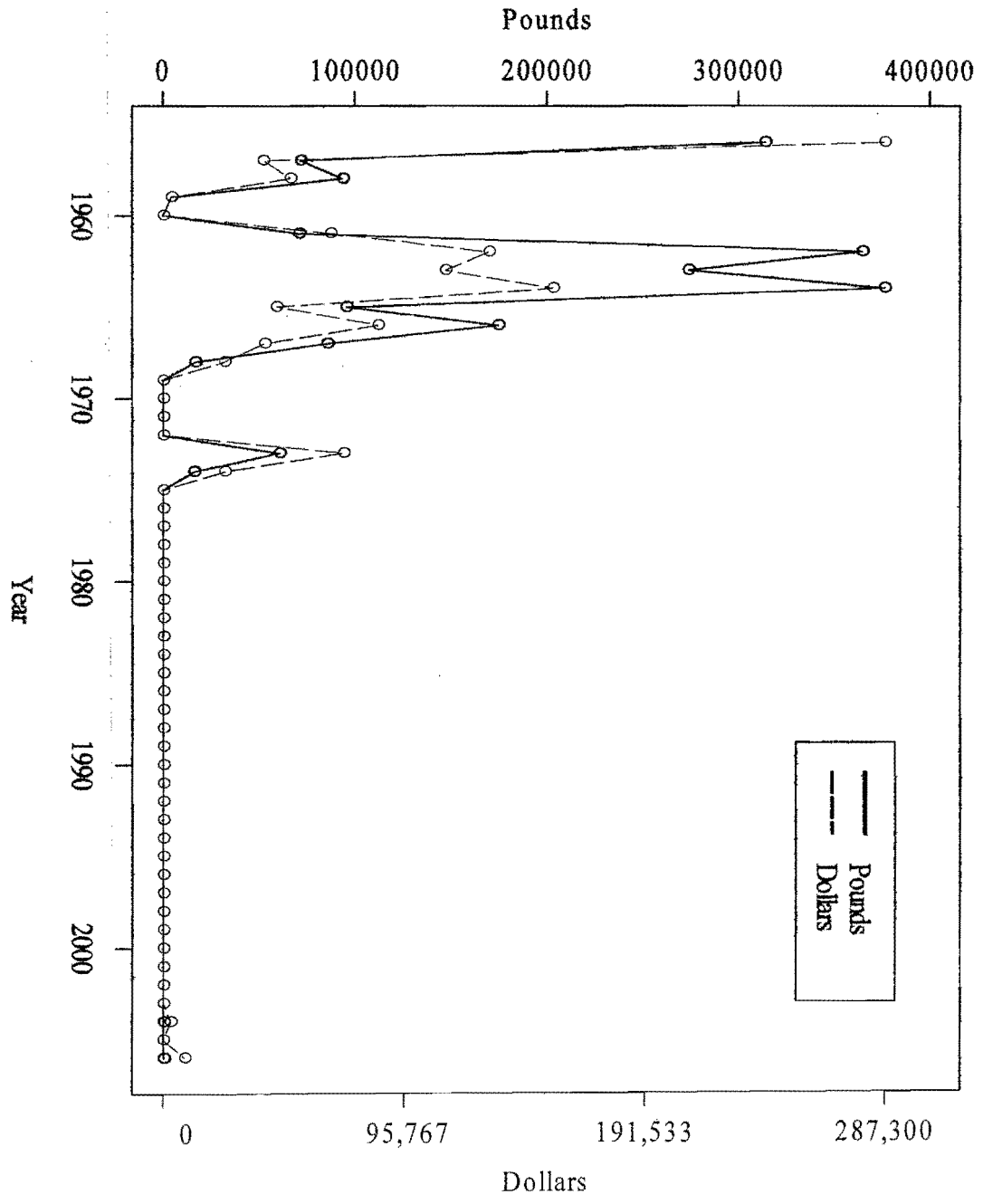


Table 2. Physico-chemical data collected during the 2006 *Argopecten* survey of Little Egg Harbor Bay.

Station	Date	Latitude midpoint	Longitude midpoint	Surface				Bottom			
				Temperature (C)	Salinity (‰)	DO (mg/l)	pH	Temperature (C)	Salinity (‰)	DO (mg/l)	pH
22	6-Nov-06	39 37.735	74 14.085	-	-	-	-	10	23	10	8.2
39	6-Nov-06	39 37.710	74 15.258	-	-	-	-	9	21	9.5	8
12	14-Nov-06	39 39.268	74 11.452	-	-	-	-	15	23	7.5	8
78	14-Nov-06	39 36.014	74 13.723	-	-	-	-	15	22	9.2	8
175	27-Nov-06	39 34.289	74 14.352	-	-	-	-	9	25	9.1	8
188	27-Nov-06	39 34.490	74 15.018	11	27	8.7	8	-	-	-	-
92	28-Nov-06	39 34.753	74 14.719	10.5	25	9	8	-	-	-	-
176	28-Nov-06	39 34.258	74 15.989	9.5	24	8.8	7.8	-	-	-	-
50	29-Nov-06	39 37.253	74 13.500	11	24	10.6	8	-	-	-	-
74	29-Nov-06	39 35.473	74 15.024	10.5	25	8.9	7.8	-	-	-	-
n				5	5	5	5	5	5	5	5
Minimum				9.5	24	8.7	7.8	9	21	7.5	8
Maximum				11	27	10.6	8	15	25	10	8.2
Mean				10.5	25.0	9.2	7.9	11.6	22.8	9.1	8.0
SD				0.6	1.2	0.8	0.1	3.1	1.5	0.9	0.1

Table 4. Station location, tow and station statistics, mean shell height, recruitment indices, and SAV from the 2006 *Argopecten* survey of Little Egg Harbor Bay.

Station	Date	Latitude	Longitude	Depth (feet)	Distance Towed (feet)	Tow Duration (min)	Average Speed (knots)**	Abundance (*Argopecten*/foot^2)	Mean$^{\alpha}$ Height (mm)	Percent Age 0	Live *Zostera* collected$^{\Delta}$?
1	6-Nov-06	39 39.773	74 12.836	4.9	178.0	1.0	1.8	0.000000	NA^{n}	NA^{0}	0
2	6-Nov-06	39 39.538	74 12.817	5.1	179.4	1.0	1.8	0.000000	NA^{n}	NA^{0}	0
3	6-Nov-06	39 39.245	74 12.784	5.7	144.5	1.0	1.4	0.000000	NA^{n}	NA^{0}	0
4	6-Nov-06	39 39.006	74 12.778	5.3	144.1	1.0	1.4	0.000000	NA^{n}	NA^{0}	0
5	6-Nov-06	39 39.254	74 12.153	4.7	149.2	1.0	1.5	0.000000	NA^{n}	NA^{0}	1
6.1	6-Nov-06	39 39.759	74 12.490	6.1	238.6	1.0	2.4	0.000000	NA^{n}	NA^{0}	0
6.2	6-Nov-06	39 39.721	74 12.483	7.6	144.0	1.0	1.4	0.000000	NA^{n}	NA^{0}	0
7	6-Nov-06	39 39.537	74 12.438	6.5	211.9	1.0	2.1	0.000000	NA^{n}	NA^{0}	1
8	6-Nov-06	39 38.977	74 12.472	5.7	134.8	1.0	1.3	0.000000	NA^{n}	NA^{0}	0
9	6-Nov-06	39 38.771	74 12.180	4.1	182.0	1.0	1.8	0.000000	NA^{n}	NA^{0}	1
10	14-Nov-06	39 38.766	74 11.527	2.7	141.0	1.0	1.4	0.000000	NA^{n}	NA^{0}	1
11	14-Nov-06	39 38.942	74 11.427	5.1	216.2	1.0	2.1	0.000000	NA^{n}	NA^{0}	0
11.5	14-Nov-06	39 39.034	74 11.299	3.5	177.1	1.0	1.7	0.000000	NA^{n}	NA^{0}	1
12	14-Nov-06	39 39.268	74 11.452	2.9	146.4	1.0	1.4	0.000000	NA^{n}	NA^{0}	1
12.5	14-Nov-06	39 39.248	74 11.360	3.7	159.6	1.0	1.6	0.000000	NA^{n}	NA^{0}	1
14	14-Nov-06	39 38.472	74 11.253	4.7	150.5	1.0	1.5	0.000000	NA^{n}	NA^{0}	0
15	6-Nov-06	39 38.501	74 11.798	3.5	183.8	1.0	1.8	0.000000	NA^{n}	NA^{0}	1
16	6-Nov-06	39 38.468	74 12.454	5.7	156.8	1.0	1.5	0.000000	NA^{n}	NA^{0}	1
17	6-Nov-06	39 38.751	74 14.063	6.1	183.5	1.0	1.8	0.000000	NA^{n}	NA^{0}	0
18	6-Nov-06	39 38.245	74 13.440	5.5	135.7	1.0	1.3	0.000000	NA^{n}	NA^{0}	1
19	6-Nov-06	39 38.097	74 12.965	4.5	155.9	1.0	1.5	0.000000	NA^{n}	NA^{0}	1
20	6-Nov-06	39 37.999	74 13.719	4.5	NA*	1.0	1.8	0.000000	NA^{n}	NA^{0}	1
21	29-Nov-06	39 37.485	74 13.752	5.3	136.3	1.0	1.3	0.000000	NA^{n}	NA^{0}	0
22	6-Nov-06	39 37.735	74 14.085	5.1	149.2	1.0	1.5	0.000000	NA^{n}	NA^{0}	0
23	6-Nov-06	39 37.989	74 14.413	5.9	134.6	1.0	1.3	0.000000	NA^{n}	NA^{0}	0
24	29-Nov-06	39 37.504	74 14.415	3.9	147.7	1.0	1.5	0.000000	NA^{n}	NA^{0}	1

Table 4. Station location, tow and station statistics, mean shell height, recruitment indices, and SAV from the 2006 *Argopecten* survey of Little Egg Harbor Bay.

Station	Date	Latitude	Longitude	Depth (feet)	Distance Towed (feet)	Tow Duration (min)	Average Speed (knots)**	Abundance (*Argopecten*/foot^2)	Mean$^{\alpha}$ Height (mm)	Percent Age 0	Live *Zostera* collected$^{\Delta}$?
25	6-Nov-06	39 37.741	74 14.688	7.0	176.6	1.0	1.7	0.000000	NA^{n}	NA^{0}	0
26	6-Nov-06	39 37.229	74 14.736	7.0	138.5	1.0	1.4	0.000000	NA^{n}	NA^{0}	0
27	29-Nov-06	39 36.751	74 14.735	5.5	116.3	1.0	1.1	0.000000	NA^{n}	NA^{0}	0
28	29-Nov-06	39 36.474	74 15.014	5.3	131.6	1.0	1.3	0.000000	NA^{n}	NA^{0}	1
29	29-Nov-06	39 36.981	74 14.387	5.7	107.8	1.0	1.1	0.000000	NA^{n}	NA^{0}	1
30	29-Nov-06	39 37.244	74 14.050	5.5	133.5	1.0	1.3	0.000000	NA^{n}	NA^{0}	0
31	29-Nov-06	39 36.731	74 14.072	5.1	151.4	1.0	1.5	0.000000	NA^{n}	NA^{0}	1
32	29-Nov-06	39 36.481	74 13.716	3.7	146.2	1.0	1.4	0.000000	NA^{n}	NA^{0}	1
33	29-Nov-06	39 36.493	74 14.389	4.7	139.6	1.0	1.4	0.000000	NA^{n}	NA^{0}	1
34	6-Nov-06	39 37.019	74 15.032	7.8	210.0	1.0	2.1	0.000000	NA^{n}	NA^{0}	0
35	29-Nov-06	39 36.727	74 15.329	6.1	127.5	1.0	1.3	0.000000	NA^{n}	NA^{0}	0
36	6-Nov-06	39 37.011	74 15.675	6.8	161.2	1.0	1.6	0.000000	NA^{n}	NA^{0}	0
37	6-Nov-06	39 37.230	74 15.359	7.2	142.0	1.0	1.4	0.000000	NA^{n}	NA^{0}	0
39	6-Nov-06	39 37.710	74 15.258	5.9	209.7	1.0	2.1	0.000000	NA^{n}	NA^{0}	0
40	6-Nov-06	39 38.319	74 14.903	6.6	175.2	1.0	1.7	0.000000	NA^{n}	NA^{0}	0
41	6-Nov-06	39 38.252	74 14.064	5.7	123.7	1.0	1.2	0.000000	NA^{n}	NA^{0}	0
42	6-Nov-06	39 38.481	74 14.371	7.3	211.3	1.0	2.1	0.000000	NA^{n}	NA^{0}	0
43	6-Nov-06	39 38.518	74 13.732	7.0	226.0	1.0	2.2	0.000000	NA^{n}	NA^{0}	0
45	6-Nov-06	39 38.247	74 12.167	5.1	136.3	1.0	1.3	0.000000	NA^{n}	NA^{0}	0
46	6-Nov-06	39 37.999	74 12.000	4.3	162.6	1.0	1.6	0.000000	NA^{n}	NA^{0}	1
47	6-Nov-06	39 38.013	74 12.480	4.3	170.6	1.0	1.7	0.000000	NA^{n}	NA^{0}	1
48	6-Nov-06	39 37.758	74 12.790	3.9	176.1	1.0	1.7	0.000000	NA^{n}	NA^{0}	1
49	6-Nov-06	39 37.489	74 13.089	5.9	156.7	1.0	1.5	0.000000	NA^{n}	NA^{0}	0
50	29-Nov-06	39 37.253	74 13.500	5.3	130.0	1.0	1.3	0.000000	NA^{n}	NA^{0}	1
51	29-Nov-06	39 36.975	74 13.743	5.5	127.5	1.0	1.3	0.000000	NA^{n}	NA^{0}	1
52	14-Nov-06	39 37.490	74 12.459	5.5	110.3	1.0	1.1	0.004464	13.0	100	1

Table 4. Station location, tow and station statistics, mean shell height, recruitment indices, and SAV from the 2006 *Argopecten* survey of Little Egg Harbor Bay.

Station	Date	Latitude	Longitude	Depth (feet)	Distance Towed (feet)	Tow Duration (min)	Average Speed (knots)**	Abundance (*Argopecten*/foot^2)	Mean$^{\alpha}$ Height (mm)	Percent Age 0	Live *Zostera* collected$^{\Delta}$?
53	14-Nov-06	39 37.509	74 12.151	5.5	145.9	1.0	1.4	0.000000	NA^{n}	NA^{0}	1
54	14-Nov-06	39 37.734	74 12.187	7.4	171.6	1.0	1.7	0.000000	NA^{n}	NA^{0}	0
55	14-Nov-06	39 37.869	74 11.811	4.3	166.4	1.0	1.6	0.000000	NA^{n}	NA^{0}	1
56	6-Nov-06	39 37.759	74 13.447	4.5	176.5	1.0	1.7	0.000000	NA^{n}	NA^{0}	1
57	14-Nov-06	39 37.237	74 12.807	4.7	172.4	1.0	1.7	0.000000	NA^{n}	NA^{0}	1
58	14-Nov-06	39 37.012	74 13.095	4.7	167.1	1.0	1.6	0.000000	NA^{n}	NA^{0}	1
59	29-Nov-06	39 36.746	74 13.431	3.9	156.6	1.0	1.5	0.000000	NA^{n}	NA^{0}	1
60	14-Nov-06	39 36.499	74 13.144	5.5	128.5	1.0	1.3	0.000000	NA^{n}	NA^{0}	1
61	29-Nov-06	39 36.246	74 14.058	3.5	156.4	1.0	1.5	0.000000	NA^{n}	NA^{0}	1
62	29-Nov-06	39 36.245	74 14.679	3.5	145.4	1.0	1.4	0.003387	24.0	100	1
63	29-Nov-06	39 36.009	74 15.045	6.1	144.4	1.0	1.4	0.000000	NA^{n}	NA^{0}	0
65	14-Nov-06	39 36.987	74 12.386	4.9	136.5	1.0	1.3	0.000000	NA^{n}	NA^{0}	1
66	14-Nov-06	39 36.730	74 12.757	4.9	159.1	1.0	1.6	0.000000	NA^{n}	NA^{0}	1
67	14-Nov-06	39 35.984	74 13.081	5.1	173.4	1.0	1.7	0.000000	NA^{n}	NA^{0}	1
68	14-Nov-06	39 35.750	74 13.419	6.6	139.1	1.0	1.4	0.000000	NA^{n}	NA^{0}	0
71	14-Nov-06	39 35.234	74 14.078	6.1	139.3	1.0	1.4	0.000000	NA^{n}	NA^{0}	0
72	14-Nov-06	39 35.102	74 14.025	4.7	131.9	1.0	1.3	0.000000	NA^{n}	NA^{0}	1
73	14-Nov-06	39 35.509	74 14.366	7.0	224.0	1.0	2.2	0.000000	NA^{n}	NA^{0}	0
74	29-Nov-06	39 35.473	74 15.024	6.3	137.4	1.0	1.4	0.000000	NA^{n}	NA^{0}	0
75	29-Nov-06	39 35.685	74 14.727	4.5	125.0	1.0	1.2	0.000000	NA^{n}	NA^{0}	0
76	29-Nov-06	39 35.990	74 14.394	3.5	142.4	1.0	1.4	0.000000	NA^{n}	NA^{0}	1
77	14-Nov-06	39 35.765	74 14.075	5.4	185.8	1.0	1.8	0.000000	NA^{n}	NA^{0}	1
78	14-Nov-06	39 36.014	74 13.723	3.9	234.9	1.0	2.3	0.000000	NA^{n}	NA^{0}	0
79	14-Nov-06	39 36.229	74 13.457	4.3	166.2	1.0	1.6	0.000000	NA^{n}	NA^{0}	1
80	14-Nov-06	39 36.556	74 12.562	5.1	165.6	1.0	1.6	0.000000	NA^{n}	NA^{0}	1
81	14-Nov-06	39 36.996	74 12.119	3.7	128.7	1.0	1.3	0.000000	NA^{n}	NA^{0}	0

Table 4. Station location, tow and station statistics, mean shell height, recruitment indices, and SAV from the 2006 *Argopecten* survey of Little Egg Harbor Bay.

Station	Date	Latitude	Longitude	Depth (feet)	Distance Towed (feet)	Tow Duration (min)	Average Speed (knots)**	Abundance (*Argopecten*/foot^2)	Mean$^{\alpha}$ Height (mm)	Percent Age 0	Live *Zostera* collected$^{\Delta}$?
82	14-Nov-06	39 37.981	74 11.518	4.7	186.3	1.0	1.8	0.000000	NA^{n}	NA^{0}	1
83	14-Nov-06	39 38.241	74 11.349	4.7	106.3	1.0	1.0	0.000000	NA^{n}	NA^{0}	1
84	14-Nov-06	39 37.223	74 12.050	3.1	163.5	1.0	1.6	0.000000	NA^{n}	NA^{0}	1
87	28-Nov-06	39 35.266	74 15.337	7.0	163.3	1.0	1.6	0.000000	NA^{n}	NA^{0}	0
88	28-Nov-06	39 35.039	74 15.665	7.2	135.5	1.0	1.3	0.000000	NA^{n}	NA^{0}	0
89	28-Nov-06	39 34.747	74 15.197	3.9	148.3	1.0	1.5	0.000000	NA^{n}	NA^{0}	1
90	28-Nov-06	39 35.002	74 15.059	4.9	180.6	1.0	1.8	0.002726	20.0	100	1
91	29-Nov-06	39 35.237	74 14.729	5.7	133.0	1.0	1.3	0.000000	NA^{n}	NA^{0}	0
92	28-Nov-06	39 34.753	74 14.719	5.7	116.1	1.0	1.1	0.000000	NA^{n}	NA^{0}	1
93	27-Nov-06	39 34.505	74 14.400	3.5	88.4	1.0	0.9	0.000000	NA^{n}	NA^{0}	0
94	14-Nov-06	39 34.824	74 13.804	5.1	220.2	1.0	2.2	0.000000	NA^{n}	NA^{0}	0
98	28-Nov-06	39 34.499	74 17.616	7.6	168.8	1.0	1.7	0.000000	NA^{n}	NA^{0}	0
99	28-Nov-06	39 34.229	74 17.310	6.1	181.1	1.0	1.8	0.000000	NA^{n}	NA^{0}	0
100	28-Nov-06	39 34.260	74 17.937	4.9	159.2	1.0	1.6	0.000000	NA^{n}	NA^{0}	0
101	28-Nov-06	39 34.232	74 18.553	5.1	149.1	1.0	1.5	0.000000	NA^{n}	NA^{0}	0
102	28-Nov-06	39 33.792	74 18.570	4.1	163.8	1.0	1.6	0.000000	NA^{n}	NA^{0}	0
103	28-Nov-06	39 33.981	74 18.913	4.9	123.2	1.0	1.2	0.000000	NA^{n}	NA^{0}	0
104	28-Nov-06	39 34.035	74 17.672	4.3	127.7	1.0	1.3	0.000000	NA^{n}	NA^{0}	0
105	28-Nov-06	39 34.247	74 16.627	5.3	168.4	1.0	1.7	0.000000	NA^{n}	NA^{0}	0
106	27-Nov-06	39 33.531	74 16.337	5.5	192.3	1.0	1.9	0.000000	NA^{n}	NA^{0}	1
107	27-Nov-06	39 33.274	74 16.029	5.1	151.3	1.0	1.5	0.000000	NA^{n}	NA^{0}	0
108	27-Nov-06	39 33.996	74 15.002	3.7	150.1	1.0	1.5	0.000000	NA^{n}	NA^{0}	0
109	27-Nov-06	39 34.265	74 15.246	5.9	166.1	1.0	1.6	0.000000	NA^{n}	NA^{0}	0
110	27-Nov-06	39 33.830	74 15.387	6.5	149.1	1.0	1.5	0.000000	NA^{n}	NA^{0}	0
111	27-Nov-06	39 33.529	74 15.654	7.0	136.3	1.0	1.3	0.000000	NA^{n}	NA^{0}	0
112	27-Nov-06	39 33.012	74 15.655	9.5	119.1	1.0	1.2	0.000000	NA^{n}	NA^{0}	0

Table 4. Station location, tow and station statistics, mean shell height, recruitment indices, and SAV from the 2006 *Argopecten* survey of Little Egg Harbor Bay.

Station	Date	Latitude	Longitude	Depth (feet)	Distance Towed (feet)	Tow Duration (min)	Average Speed (knots)**	Abundance (*Argopecten*/foot^2)	Mean$^{\alpha}$ Height (mm)	Percent Age 0	Live *Zostera* collected$^{\Delta}$?
113	27-Nov-06	39 32.705	74 15.808	5.4	95.0	1.0	0.9	0.000000	NA^{n}	NA^{0}	0
114	27-Nov-06	39 32.507	74 15.735	5.5	235.0	1.0	2.3	0.000000	NA^{n}	NA^{0}	0
115	27-Nov-06	39 32.250	74 15.995	6.7	160.8	1.0	1.6	0.000000	NA^{n}	NA^{0}	0
116	27-Nov-06	39 32.011	74 16.949	3.3	181.8	1.0	1.8	0.000000	NA^{n}	NA^{0}	0
117	27-Nov-06	39 33.363	74 15.297	3.7	186.3	1.0	1.8	0.000000	NA^{n}	NA^{0}	1
118	27-Nov-06	39 33.773	74 16.014	7.0	190.6	1.0	1.9	0.000000	NA^{n}	NA^{0}	0
119	27-Nov-06	39 34.007	74 15.691	8.3	126.6	1.0	1.2	0.000000	NA^{n}	NA^{0}	0
120	14-Nov-06	39 35.310	74 13.792	5.9	NA*	0.5	1.0	0.000000	NA^{n}	NA^{0}	0
121	14-Nov-06	39 36.692	74 12.525	3.7	142.2	1.0	1.4	0.000000	NA^{n}	NA^{0}	1
122	14-Nov-06	39 36.301	74 12.792	6.1	NA	0.4	1.0	0.000000	NA^{n}	NA^{0}	0
129	28-Nov-06	39 35.500	74 16.337	7.0	172.1	1.0	1.7	0.000000	NA^{n}	NA^{0}	0
130	28-Nov-06	39 35.262	74 16.006	4.9	167.4	1.0	1.7	0.000000	NA^{n}	NA^{0}	0
131	28-Nov-06	39 35.259	74 16.662	6.8	162.6	1.0	1.6	0.000000	NA^{n}	NA^{0}	0
135	28-Nov-06	39 36.007	74 18.268	6.4	175.3	1.0	1.7	0.000000	NA^{n}	NA^{0}	0
138	27-Nov-06	39 32.499	74 17.596	2.5	98.1	1.0	1.0	0.000000	NA^{n}	NA^{0}	0
139	27-Nov-06	39 32.617	74 17.938	2.8	99.2	1.0	1.0	0.000000	NA^{n}	NA^{0}	0
141	27-Nov-06	39 32.752	74 16.720	2.9	209.5	1.0	2.1	0.000000	NA^{n}	NA^{0}	0
142	27-Nov-06	39 32.443	74 16.998	2.7	62.7	1.0	0.6	0.000000	NA^{n}	NA^{0}	0
143	27-Nov-06	39 32.731	74 17.352	1.8	93.1	1.0	0.9	0.000000	NA^{n}	NA^{0}	0
146	27-Nov-06	39 32.273	74 17.259	4.7	210.7	1.0	2.1	0.000000	NA^{n}	NA^{0}	0
148	28-Nov-06	39 34.476	74 18.246	6.4	143.6	1.0	1.4	0.000000	NA^{n}	NA^{0}	0
149	28-Nov-06	39 34.494	74 18.888	6.6	140.4	1.0	1.4	0.000000	NA^{n}	NA^{0}	0
152	28-Nov-06	39 33.983	74 19.907	5.3	102.3	1.0	1.0	0.000000	NA^{n}	NA^{0}	0
153	28-Nov-06	39 33.755	74 19.879	5.1	134.7	1.0	1.3	0.000000	NA^{n}	NA^{0}	0
154	28-Nov-06	39 33.477	74 19.540	3.1	115.1	1.0	1.1	0.000000	NA^{n}	NA^{0}	0
156	28-Nov-06	39 33.262	74 18.667	2.3	124.7	1.0	1.2	0.000000	NA^{n}	NA^{0}	0

Table 4. Station location, tow and station statistics, mean shell height, recruitment indices, and SAV from the 2006 *Argopecten* survey of Little Egg Harbor Bay.

Station	Date	Latitude	Longitude	Depth (feet)	Distance Towed (feet)	Tow Duration (min)	Average Speed (knots)**	Abundance (*Argopecten*/foot^2)	Mean$^{\alpha}$ Height (mm)	Percent Age 0	Live *Zostera* collected$^{\Delta}$?
157	28-Nov-06	39 33.493	74 18.899	2.5	131.6	1.0	1.3	0.000000	NA^{n}	NA^{0}	0
158	28-Nov-06	39 33.748	74 19.247	3.1	197.6	1.0	2.0	0.000000	NA^{n}	NA^{0}	0
159	28-Nov-06	39 33.242	74 19.236	4.1	155.5	1.0	1.5	0.000000	NA^{n}	NA^{0}	0
161	28-Nov-06	39 34.754	74 20.208	4.7	155.7	1.0	1.5	0.000000	NA^{n}	NA^{0}	0
162	27-Nov-06	39 32.759	74 18.573	2.7	150.0	1.0	1.5	0.000000	NA^{n}	NA^{0}	0
163	28-Nov-06	39 34.756	74 17.944	8.0	102.7	1.0	1.0	0.000000	NA^{n}	NA^{0}	0
166	28-Nov-06	39 34.766	74 17.302	7.6	159.7	1.0	1.6	0.000000	NA^{n}	NA^{0}	0
167	28-Nov-06	39 34.493	74 16.968	5.5	140.3	1.0	1.4	0.000000	NA^{n}	NA^{0}	0
168	28-Nov-06	39 34.752	74 16.662	5.5	166.7	1.0	1.6	0.000000	NA^{n}	NA^{0}	0
169	27-Nov-06	39 34.008	74 16.356	7.0	151.8	1.0	1.5	0.003242	42.0	0.0	0
170	27-Nov-06	39 32.987	74 16.316	4.3	177.8	1.0	1.8	0.000000	NA^{n}	NA^{0}	1
171	27-Nov-06	39 32.502	74 16.326	3.8	100.2	1.0	1.0	0.000000	NA^{n}	NA^{0}	0
172	27-Nov-06	39 32.206	74 16.596	2.9	132.0	1.0	1.3	0.000000	NA^{n}	NA^{0}	0
173	27-Nov-06	39 33.760	74 14.943	2.7	171.9	1.0	1.7	0.000000	NA^{n}	NA^{0}	0
174	27-Nov-06	39 33.566	74 14.861	3.7	195.7	1.0	1.9	0.000000	NA^{n}	NA^{0}	0
175	27-Nov-06	39 34.289	74 14.352	3.7	167.8	1.0	1.7	0.000000	NA^{n}	NA^{0}	0
176	28-Nov-06	39 34.258	74 15.989	7.2	149.6	1.0	1.5	0.000000	NA^{n}	NA^{0}	0
177	28-Nov-06	39 34.500	74 16.336	7.0	98.1	1.0	1.0	0.000000	NA^{n}	NA^{0}	0
178	28-Nov-06	39 34.764	74 15.980	2.9	149.6	1.0	1.5	0.000000	NA^{n}	NA^{0}	0
179	28-Nov-06	39 34.987	74 16.319	7.0	117.2	1.0	1.2	0.000000	NA^{n}	NA^{0}	0
180	28-Nov-06	39 35.003	74 16.950	6.4	171.5	1.0	1.7	0.000000	NA^{n}	NA^{0}	0
184	28-Nov-06	39 35.671	74 18.396	6.6	135.0	1.0	1.3	0.000000	NA^{n}	NA^{0}	0
185	28-Nov-06	39 36.254	74 17.928	5.7	176.4	1.0	1.7	0.000000	NA^{n}	NA^{0}	0
186	28-Nov-06	39 35.485	74 18.867	5.5	97.5	1.0	1.0	0.000000	NA^{n}	NA^{0}	0
187	28-Nov-06	39 34.962	74 19.464	6.4	146.0	1.0	1.4	0.000000	NA^{n}	NA^{0}	0
188	27-Nov-06	39 34.490	74 15.018	3.5	155.0	1.0	1.5	0.000000	NA^{n}	NA^{0}	1

Table 4. Station location, tow and station statistics, mean shell height, recruitment indices, and SAV from the 2006 *Argopecten* survey of Little Egg Harbor Bay.

Station	Date	Latitude	Longitude	Depth (feet)	Distance Towed (feet)	Tow Duration (min)	Average Speed (knots)**	Abundance (*Argopecten*/foot^2)	Mean$^{\alpha}$ Height (mm)	Percent Age 0	Live *Zostera* collected$^{\Delta}$?
189	27-Nov-06	39 34.515	74 15.357	3.1	216.3	1.0	2.1	0.000000	NA^{n}	NA^{0}	1

Mean Height^{a}: all mean lengths based on n = 1.

Coordinates for station 122 are the start point (not midpoint, which was not recorded).

NA* = Not available because coordinates for either midpoint or endpoint were not recorded.

Speed (knots)** = calculated from total distance and total time except for stations 20, 120, 122. For these three stations, the average speed as noted on the field data sheet was used.

NA^{0} = Not available because no *Argopecten* were collected. Therefore, calculating % Age 0 results in division by 0.

NA^{n} = Not available (station n = 0).

Δ = Live *Zostera marina* or *Ruppia maritima* collected = 1, Live *Z. marina* or *R. maritima* not collected = 0.

Table 5. Estimated *Argopecten* abundance in Little Egg Harbor Bay (2005 and 2006).

	2006 Lower Confidence Interval	2006 Point Estimate of Abundance	2006 Upper Confidence Interval
Total scallop abundance (Ages 0 and 1+)	39,140	46,773	56,305
Abundance of age 1+ scallops only	9,183	10,974	13,210
Bushels of age 1+ scallops (500 scallops/bu.)	18	22	26
Bushels of age 1+ scallops (600 scallops/bu.)	15	18	22
Bushels of age 1+ scallops (700 scallops/bu.)	13	16	19

	2005* Lower Confidence Interval	2005* Point Estimate of Abundance	2005* Upper Confidence Interval
Total scallop abundance (Ages 0 and 1+)	439,831	528,538	630,744
Abundance of age 1+ scallops only	36,435	43,783	52,250
Bushels of age 1+ scallops (500 scallops/bu.)	73	88	105
Bushels of age 1+ scallops (600 scallops/bu.)	61	73	87
Bushels of age 1+ scallops (700 scallops/bu.)	52	63	75

*Note that 2005 age 1+ values differ slightly from those reported in Celestino (2006b). See present report for explanation.

Figure 1. Map of study area for the 2006 Argopecten irradians survey of Little Egg Harbor Bay.

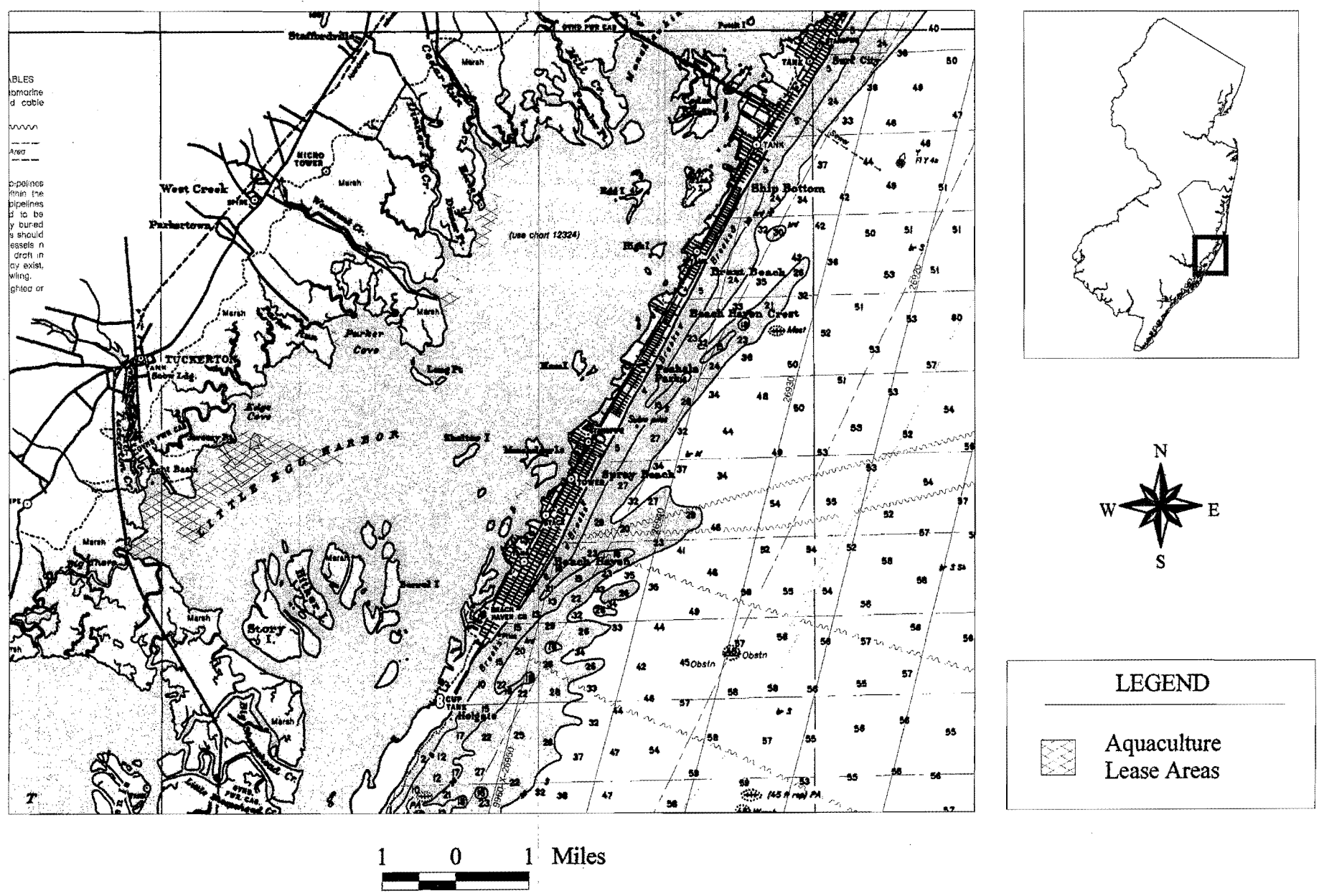
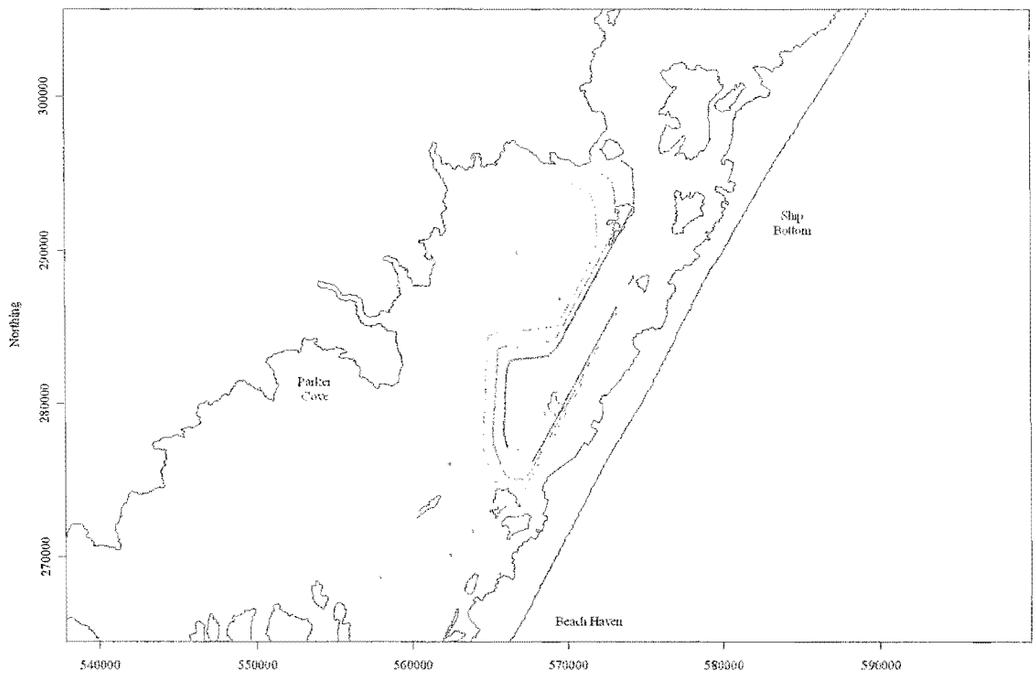


Figure 4. Bivariate linear interpolation of physico-chemical data in association with the 2006 *Argopecten* survey of Little Egg Harbor Bay: a) = Temperature (°C), b) = Salinity (‰), c) = Dissolved Oxygen (mg/l). Asterisks denote locations of samples.

a)



b)

c)

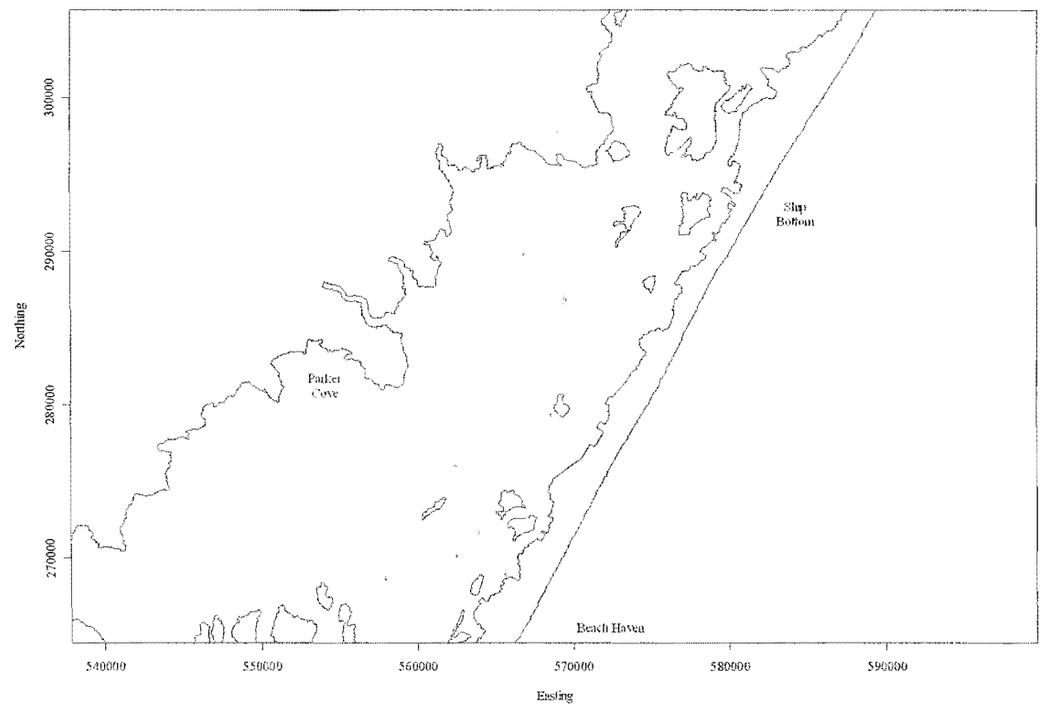


Figure 6. Station locations for the 2006 survey of Argopecten irradians in Little Egg Harbor Bay.

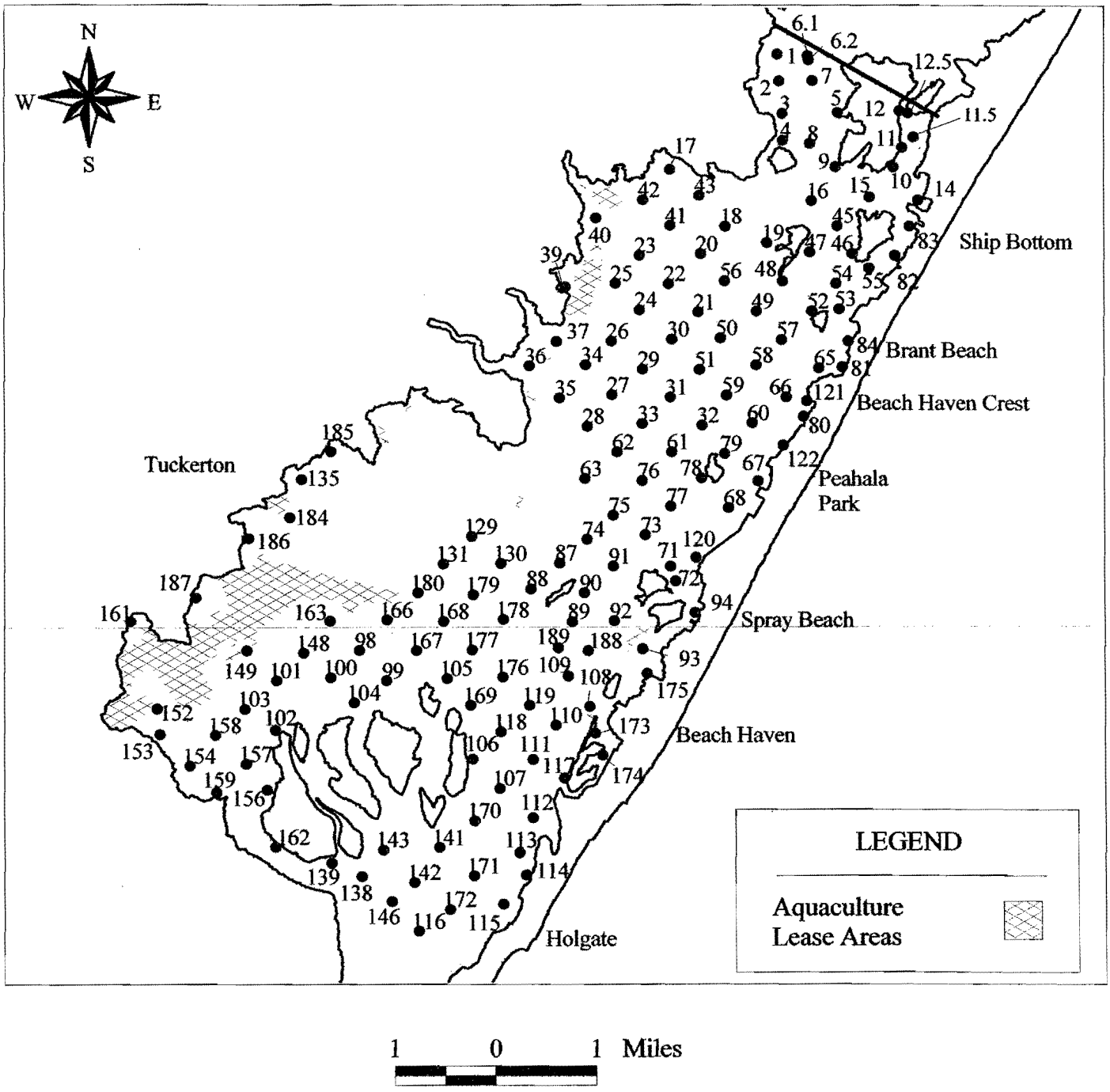


Figure 8. Argopecten irradians distribution and abundance in Little Egg Harbor Bay (2006).

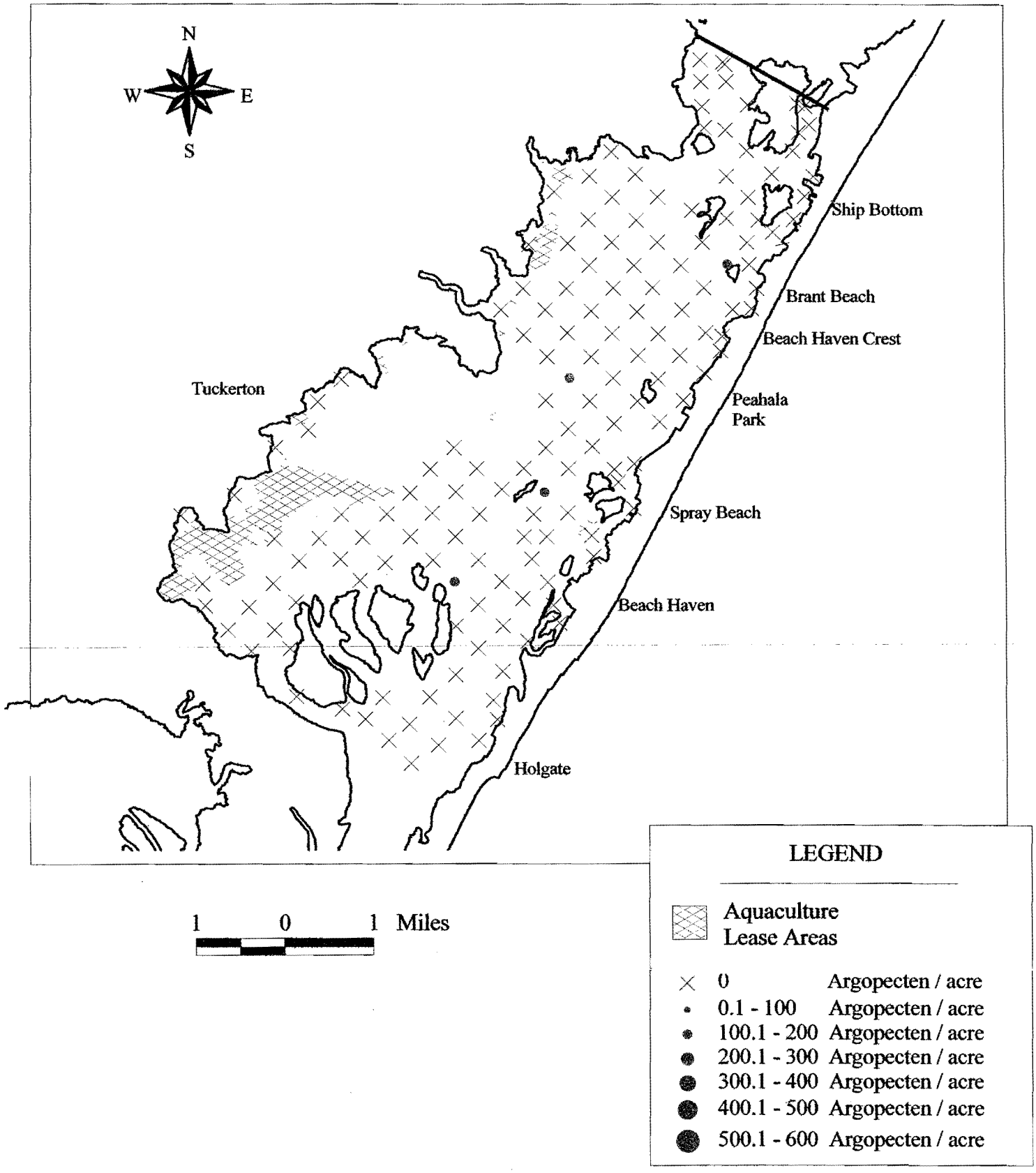


Figure 9. Argopecten irradians distribution and abundance in Little Egg Harbor Bay between fall 2005 and fall 2006.

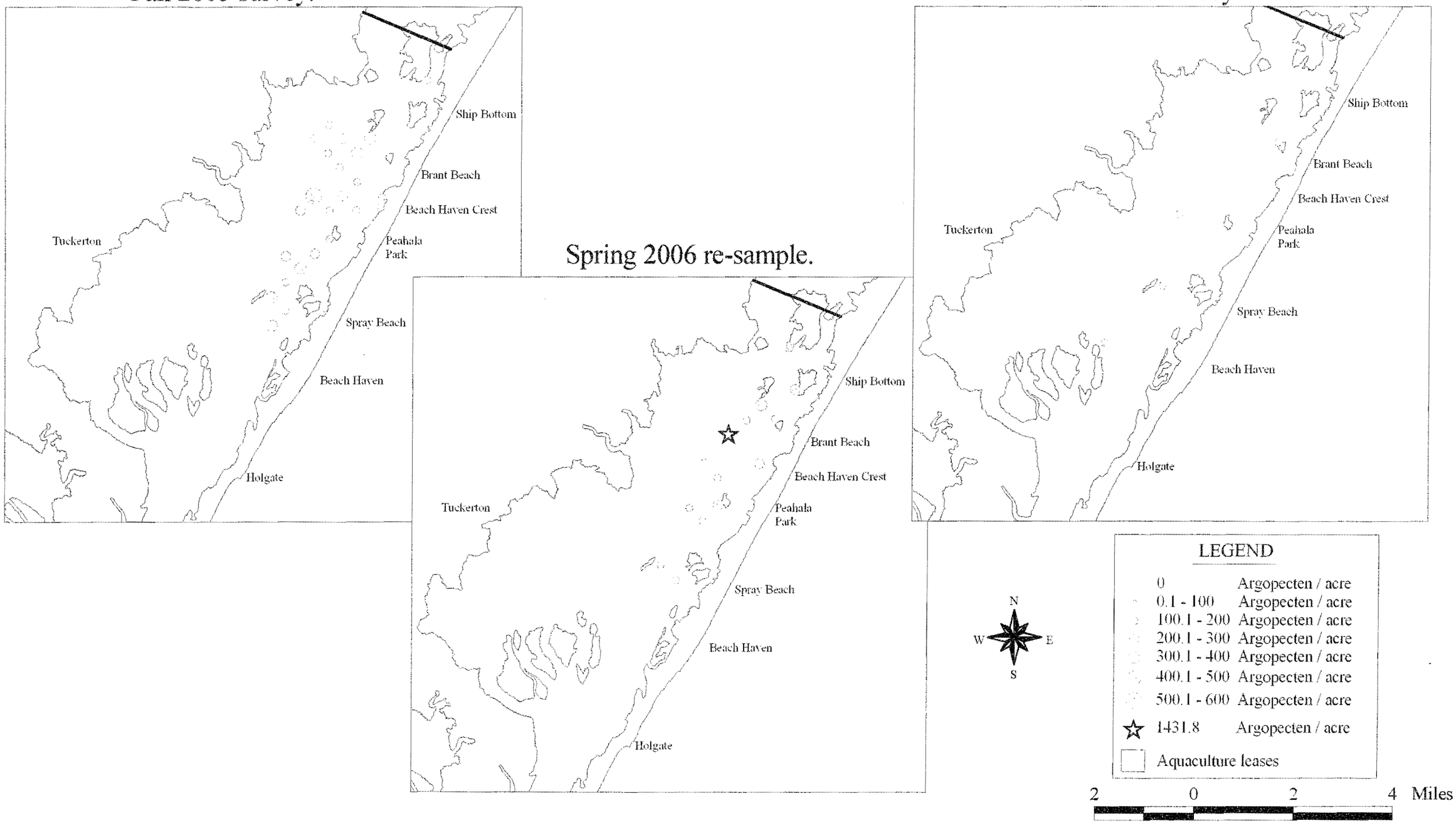


Figure 10. *Argopecten* shell-height frequency and percent-frequency plots. a) 2005 (solid black) and 2006 (red hatched) *Argopecten* shell height-frequency plot with 1-mm groupings. b) 2005 (solid black) and 2006 (red hatched) *Argopecten* shell height-percent-frequency plot with 1-mm groupings. c) 2005 (solid black) and 2006 (red hatched) *Argopecten* shell height-frequency plot with 5-mm groupings. d) 2005 (solid black) and 2006 (red hatched) *Argopecten* shell height-percent-frequency plot with 5-mm groupings. Note: for b) and d), percent-frequency = bin width × density.

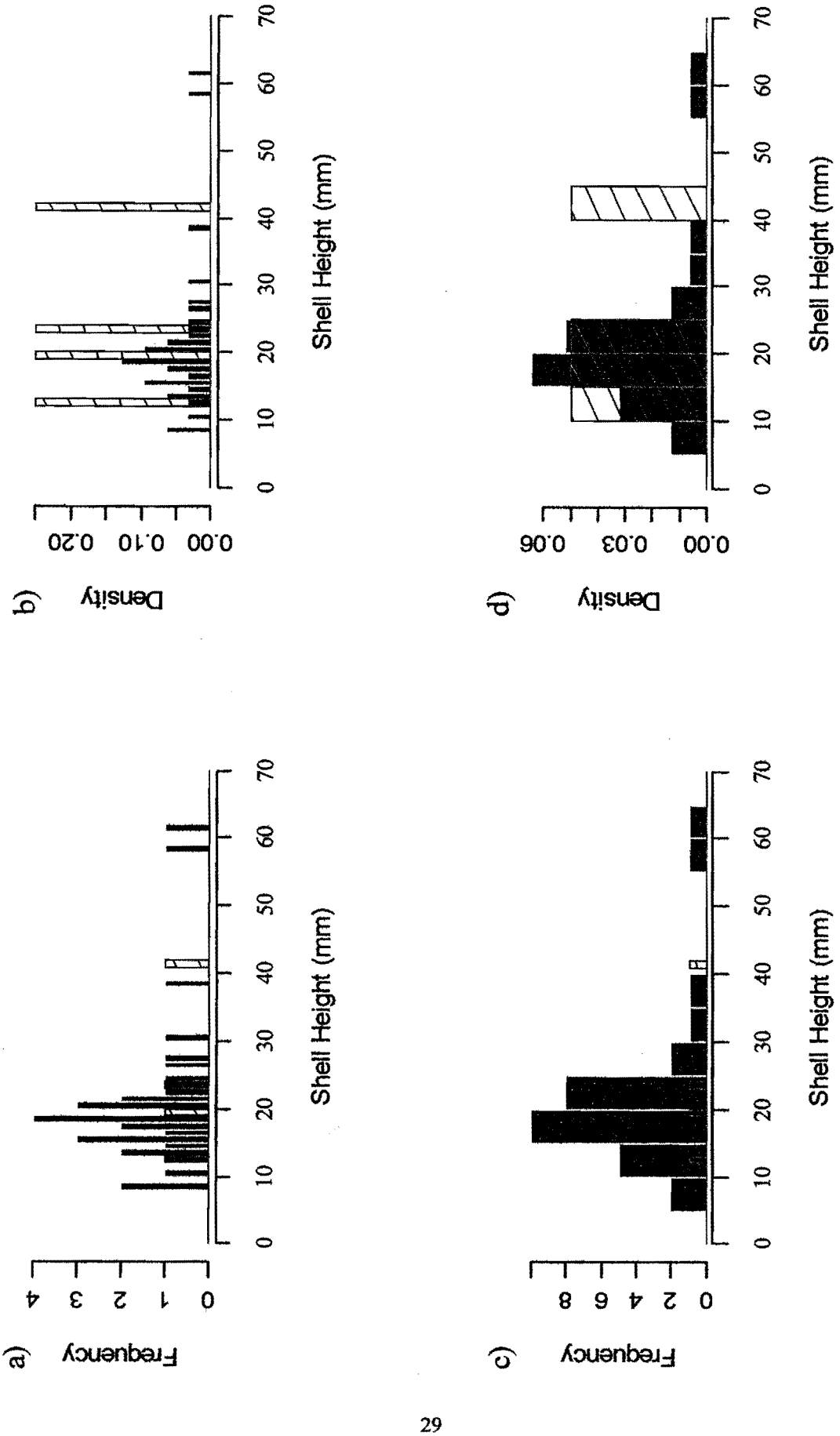
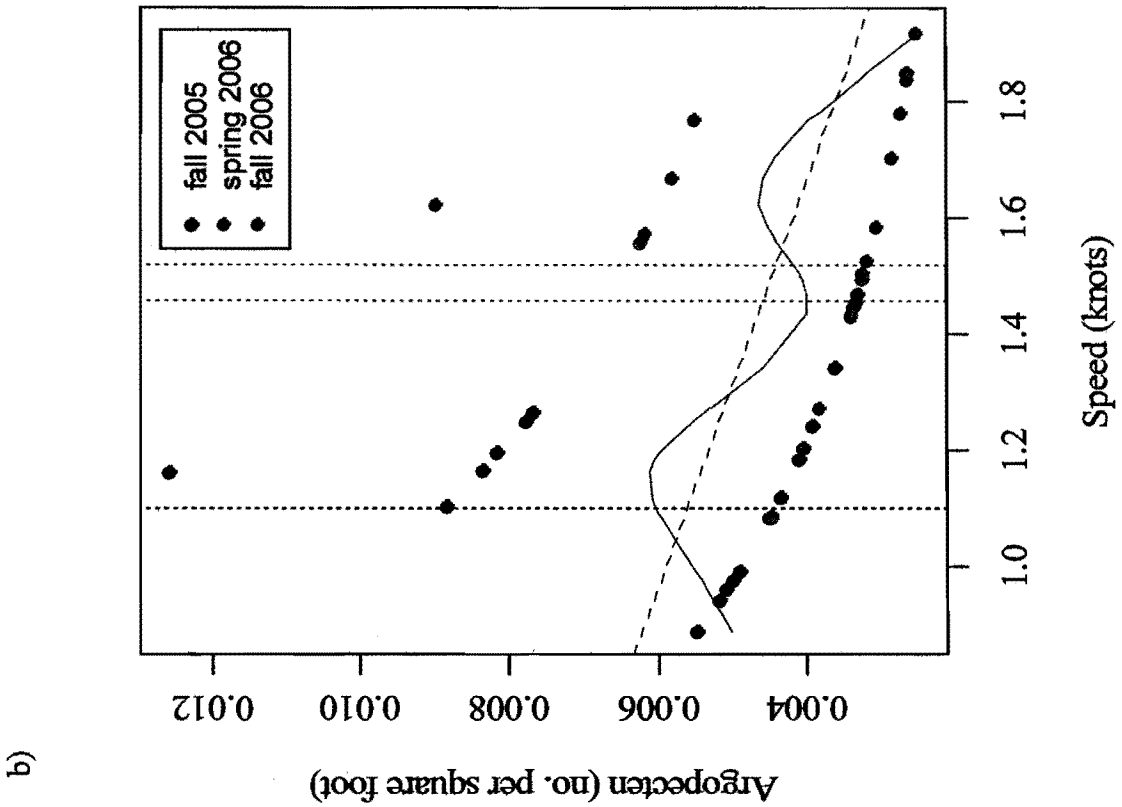


Figure 11. *Argopecten*-vessel-speed relationship: all surveys combined. a) Plot of *Argopecten* versus average vessel speed. Color of point in plot denotes sampling period (see plot legend). Several lines have been added to the plot: dotted purple = linear regression line, solid blue = cubic smoothing spline, vertical black dotted = mean vessel speed from fall 2005 survey where *Argopecten* abundance > 0, vertical red dotted = mean vessel speed from spring 2006 survey where *Argopecten* abundance > 0, and vertical green dotted = mean vessel speed from fall 2006 survey where *Argopecten* abundance > 0. b) Same as plot a), except that the suspected "outlier" has been removed. Symbol and line conventions are the same as those used in plot a).



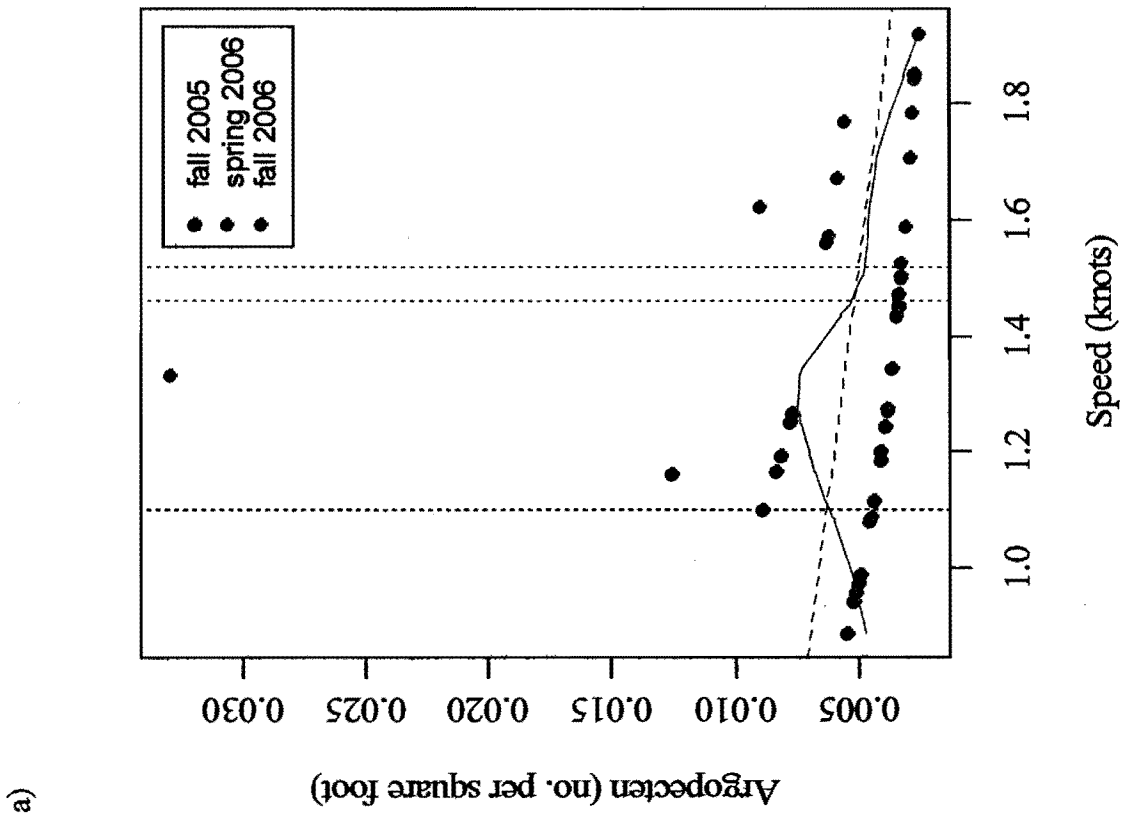
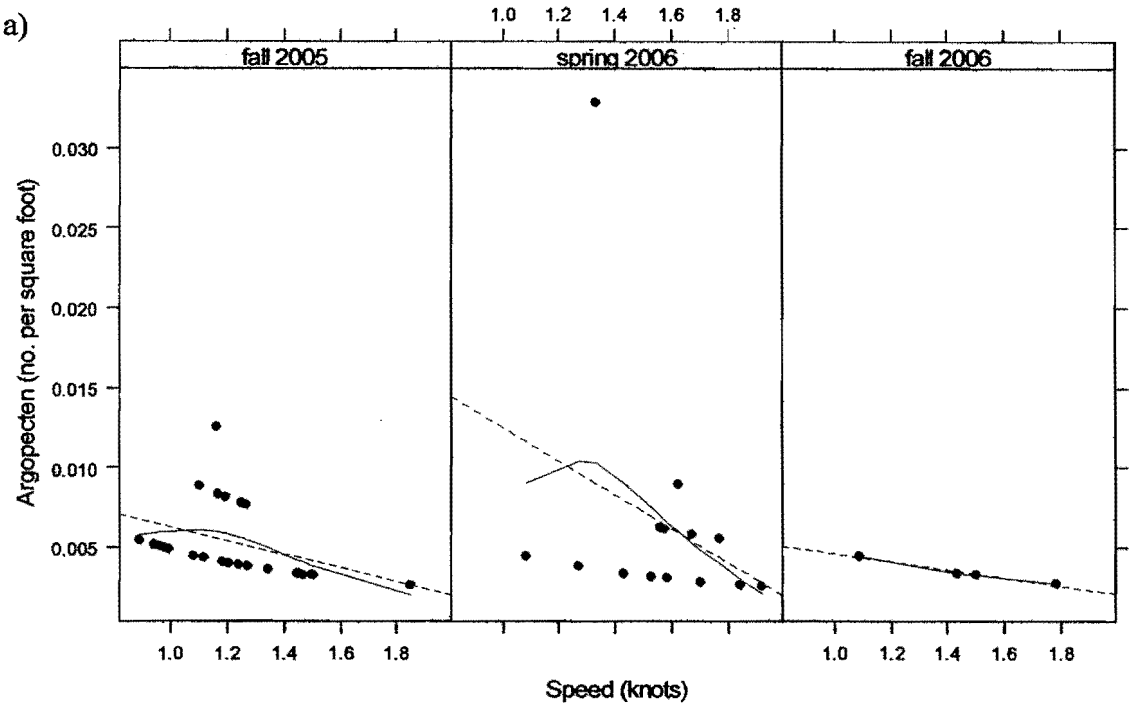


Figure 12. *Argopecten*-vessel-speed relationship: each survey individually. a) Plot of *Argopecten* versus average vessel speed. A linear regression line (red dotted line) and cubic smoothing spline (solid blue line) have been added to the plots. b) Same as plot a), except that the suspected "outlier" has been removed. Line conventions are the same as those used in plot a).

a)



b)

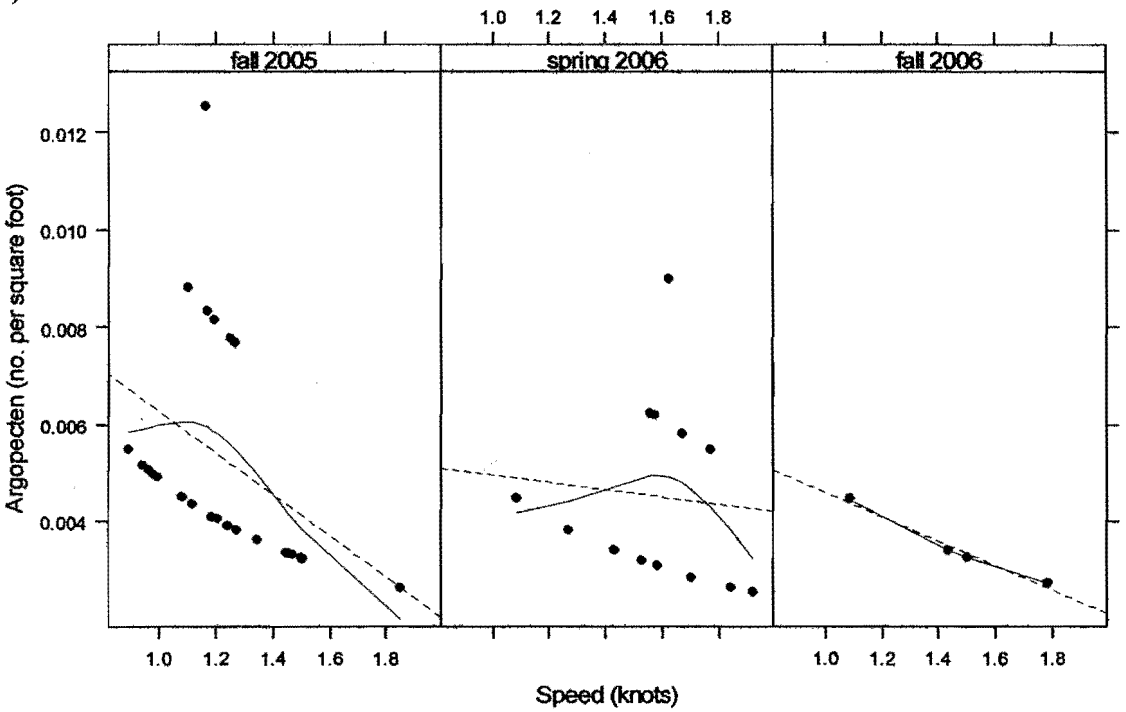


Figure 15. Distribution of submerged aquatic vegetation (SAV) in Little Egg Harbor Bay between fall 2005 and fall 2006.