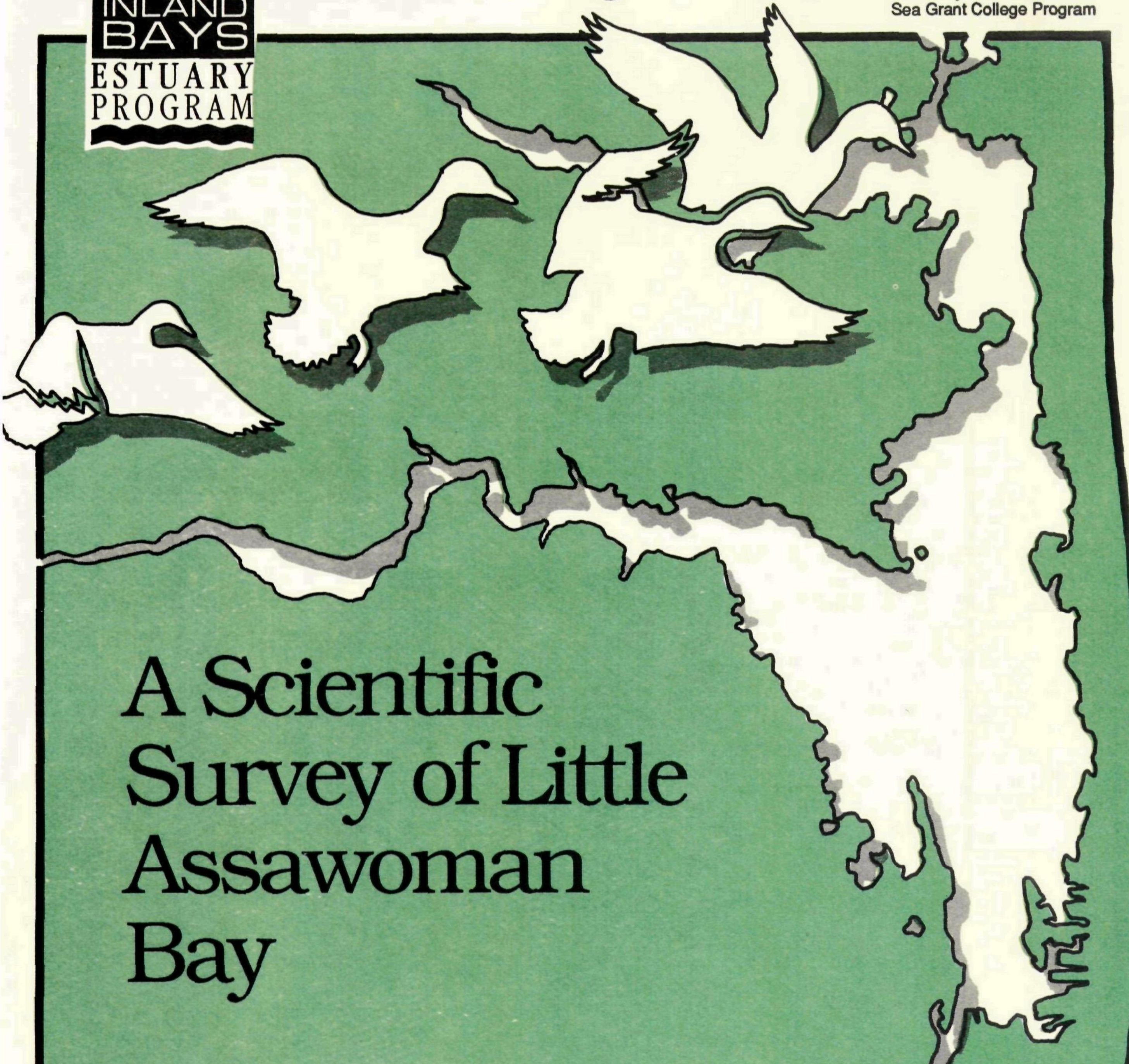
DELAWARE INLAND BAYS ESTUARY PROGRAM

## A Day in the Life of Delaware's Forgotten Bay:

University of Delaware Sea Grant College Program



# A Scientific Survey of Little Assawoman Bay

Production of this report was sponsored by the Inland Bays Estuary Program with additional support from the University of Delaware Sea Grant College Program

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## 12 June 1991


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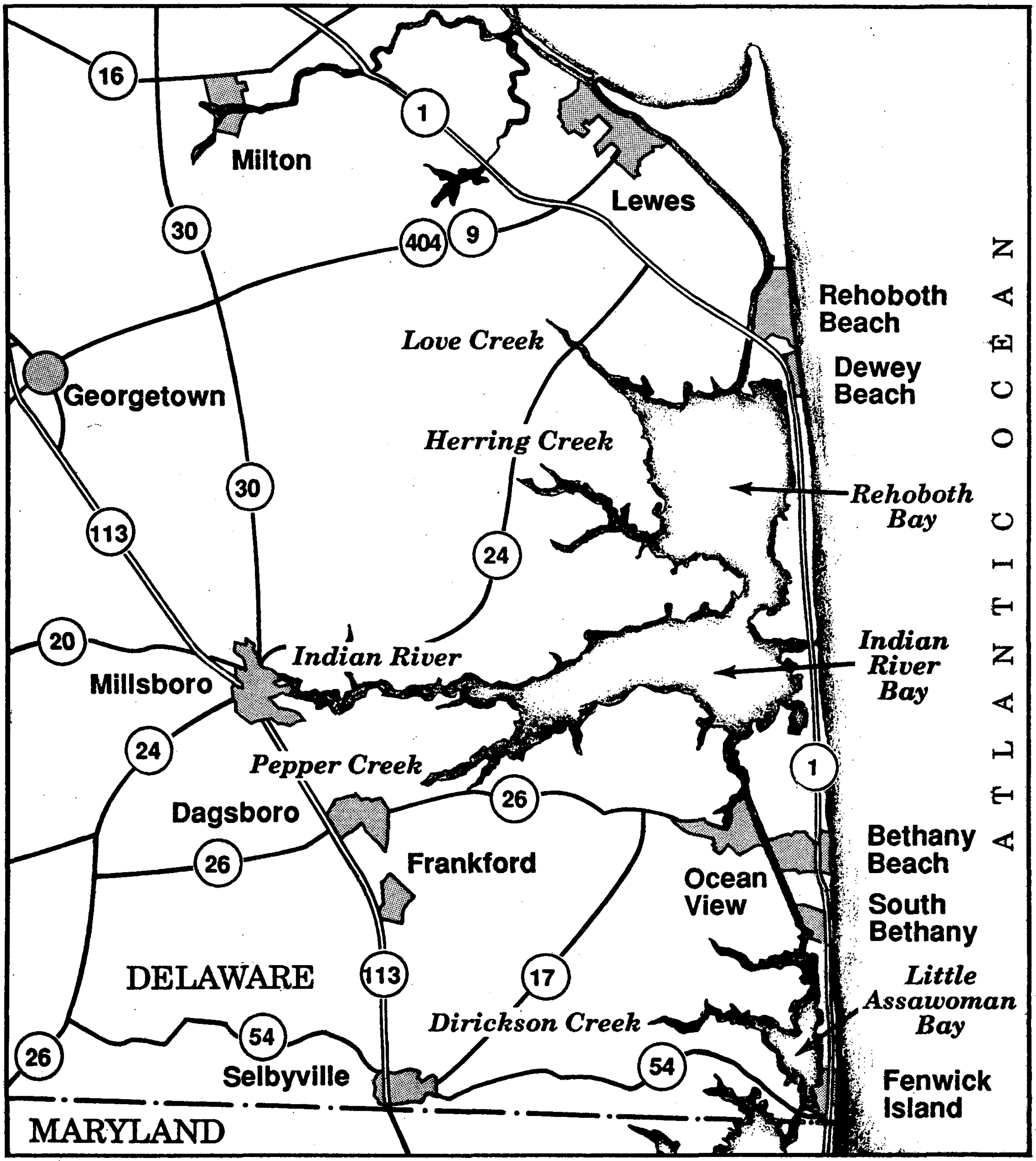

16
1
Milton
Lewes
30
404
9
Rehoboth
Beach
Love Creek
Dewey
Beach
Georgetown
Herring Creek
30
Rehoboth
Bay
113
24
ATLANTIC OCEAN
20
Indian River
Indian
River
Bay
Millsboro
24
Pepper Creek
1
26
Dagsboro
Bethany
Beach
26
Frankford
Ocean
View
South
Bethany
DELAWARE
113
17
Little
Assawoman
Bay
Dirickson Creek
54
26
54
Selbyville
Fenwick
Island
MARYLAND

# INTRODUCTION

*by Kent S. Price*

In 1987, Governor Michael N. Castle nominated Delaware's Inland Bays—Rehoboth, Indian River, and Little Assawoman bays—for inclusion in the National Estuary Program, which seeks to protect, preserve, and restore key U.S. estuaries. One year later, the U.S. Environmental Protection Agency accepted the Inland Bays into the program.

The Inland Bays Estuary Program is administered by staff within the Delaware Department of Natural Resources and Environmental Control. It is, however, a multi-agency, multi-level program effort. The Department of Health and Social Services, Sussex County Council, and U.S. Environmental Protection Agency, as well as the Department of Natural Resources and Environmental Control are all represented on the Executive Council. Input from scientists and the many interested and affected organizations and individuals is brought to the program through the Scientific and Technical Advisory Committee (STAC) and the Citizens Advisory Committee (CAC).

The STAC of the Inland Bays is conducting a "characterization" of the bays that will consist of assembling historic and present water quality and living resources data and then analyzing that data to identify the most urgent environmental problems in these estuaries. Subcontractors have been (or will be) selected to conduct the characterization and research involving (1) quantification of groundwater nutrient contributions to the Inland Bays, (2) definition of hydrodynamic transport processes influencing nutrient distribution within the Inland Bays, (3) quantification of ambient levels of phosphorus and nitrogen and nutrient cycling in the Inland Bays, and (4) developing a strategy for using living resources as an indicator of water quality in the Inland Bays.

The Inland Bay that essentially has been ignored in previous studies and thus suffers from a notable lack of historic data is Little Assawoman Bay. To learn more about this scientifically neglected member of the Inland Bays, the STAC, under the leadership of Dr. William Ullman as principal scientist, designed a comprehensive, integrated set of field experiments and observations that would allow for the establishment of a baseline of information facilitating the characterization process. This study involved representatives of federal and state agencies, the university scientific community, and individuals and firms from the private sector. In all likelihood, more data were collected on Little Assawoman Bay during this single day than in all previous studies. The data and the preliminary analyses contained in this report represent a snapshot in the life of Little Assawoman Bay. Although few if any conclusions concerning long-term trends may be drawn from this study, it does considerably strengthen our understanding of Little Assawoman Bay and allow us to better compare conditions in this bay with those of Rehoboth and Indian River Bay, which have been studied more intensely.

The STAC views this study as the first in a comprehensive series of studies to better understand Delaware's Inland Bays.

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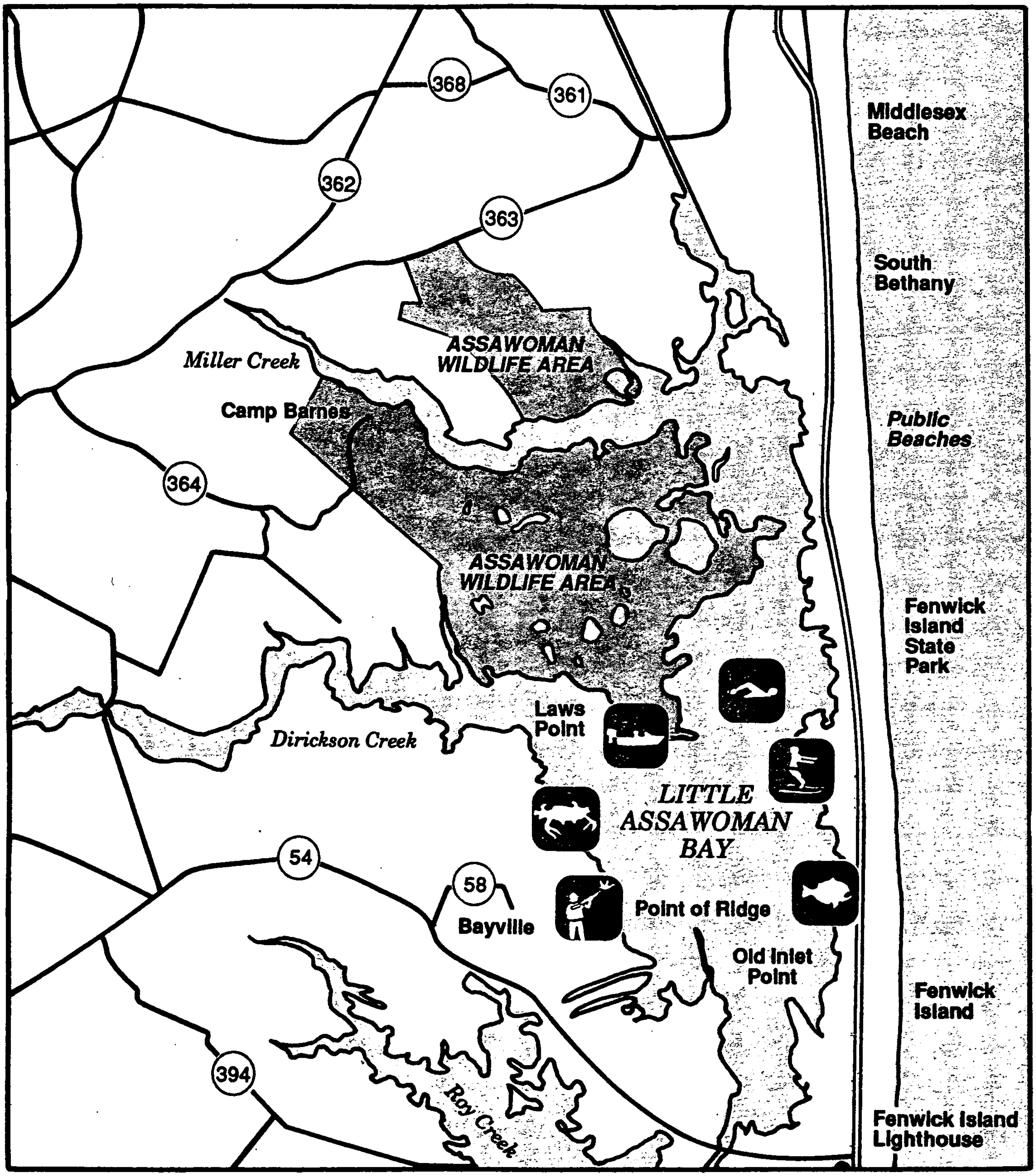


368
361
362
363
364
54
58
394
Middlesex Beach
South Bethany
Public Beaches
Fenwick Island State Park
Fenwick Island
Fenwick Island Lighthouse
ASSAWOMAN WILDLIFE AREA
ASSAWOMAN WILDLIFE AREA
Miller Creek
Camp Barnes
Laws Point
Dirickson Creek
LITTLE ASSAWOMAN BAY
Point of Ridge
Bayville
Old Inlet Point
Roy Creek

## BASE-FLOW STREAM DISCHARGE MEASUREMENTS

*by A. Scott Andres, Kathleen R. Butoryak, and Edmund M. Grace*

Stream discharge measurements under base-flow conditions were made on Bearhole Ditch at Bunting, Beaver Dam Branch at Bayard, and Agricultural Ditch at Bayard. Samples for nutrient determination were also collected at the same locations. Discharge was 1.63 cubic feet per second (cfs) at Bearhole Ditch, 0.27 cfs at Beaver Dam Branch, and 0.35 cfs at Agricultural Ditch. Accuracy is estimated to be in the range of +8–15%. The Bearhole Ditch site had been measured 14 times by the U.S. Geological Survey (USGS) previous to this measurement. The Beaver Dam Branch and Agricultural Ditch sites had not been measured previously.

Given the lack of precipitation for about one month prior to the field day, the measurements are representative of the low end of the range of discharges. For example, the recent Bearhole Ditch measurement is similar to the June 23, 1988, measured value of 1.23 cfs (Talley and Simmons, 1988), which was also made after a similar period of dry weather. The range of 14 previous discharge measurements of Bearhole Ditch is 0.18 cfs (Oct. 16, 1987) to 7.71 cfs (Aug. 27, 1969) (Talley and Simmons, 1988).

Measurements of base flow are representative of the groundwater component of stream flow for the drainage basin area upstream of the measurement point. The flow in Bearhole Ditch represents a unit discharge of 0.25 cfs per square mile and in both Beaver Dam Branch and Agricultural Ditch, 0.23 cfs per square mile. The similarity in unit discharges indicates that all of the drainage basins have similar geologic, soils, and hydrologic characteristics.

The results of water sample analyses and loading rates for selected constituents are contained in Table 1.

Discharge measurements were made using the current meter method described by Buchanan and Somers (1969). Equipment and technical assistance were provided by Robert Simmons, USGS Water Resources Division. The measurement sheets will be kept on file at the USGS office in Dover.

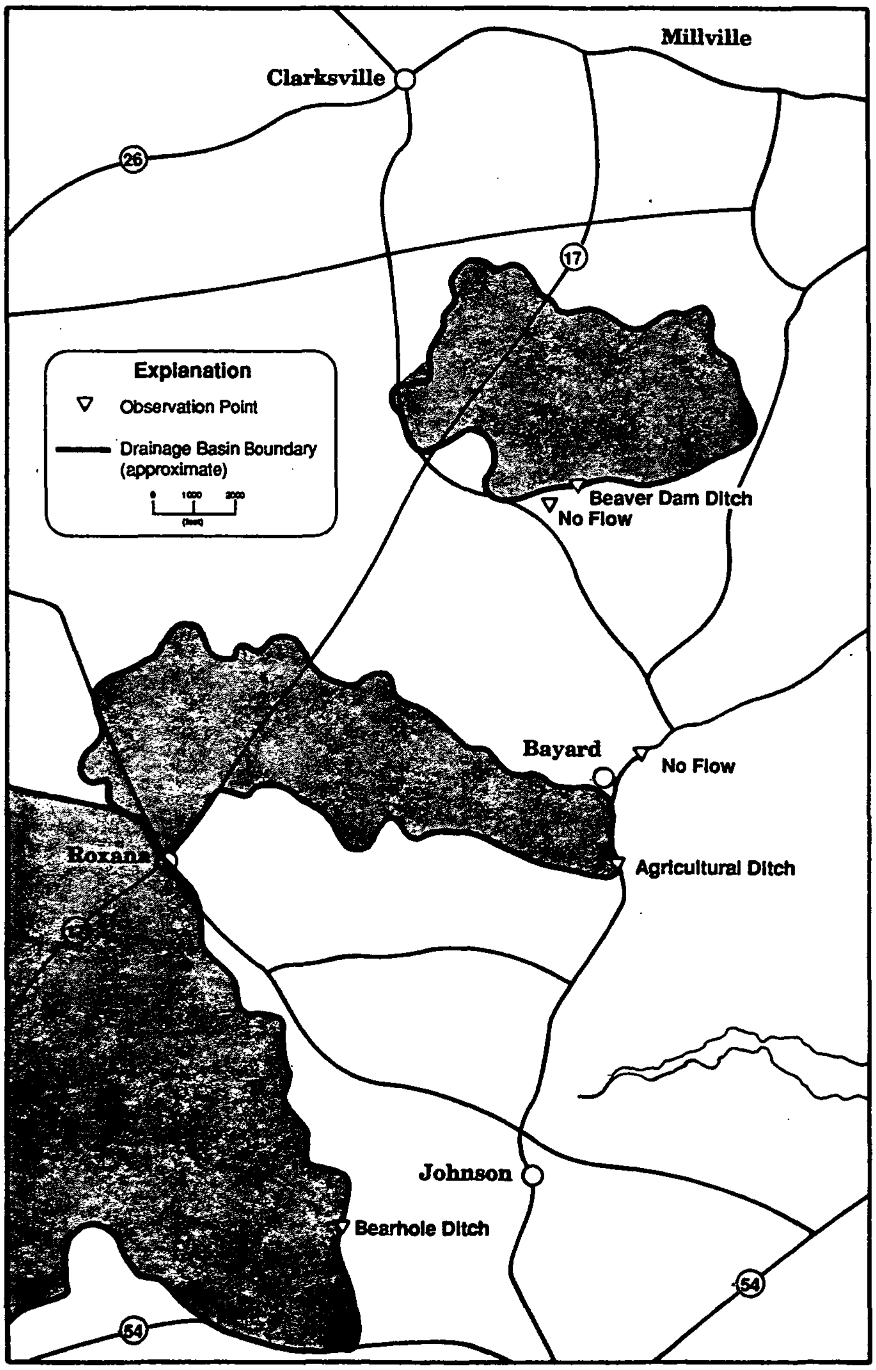
| *Stream* | $NO_3$-*N* | $NO_2$-*N* | $NH_4$-*N* | $H_4SiO_4$ | $PO_4$ |
|---|---|---|---|---|---|
| Bearhole Ditch | 1.92/7.58 | .025/.1 | .08/.319 | 23/90.5 | .048/.192 |
| Agricultural Ditch | 1.29/1.09 | .012/.01 | .032/.027 | 23/19.7 | .07/.06 |
| Beaver Dam Ditch | 86/.561 | .015/.01 | .243/.16 | 25/16.5 | .058/.038 |

**Table 1. Results of chemical analyses and calculated loading rates given in mg/l and kg/d.**

**References**

Buchanan, T. J., and W. P. Somers. 1969. Discharge measurements at gaging stations. *Techniques of Water-Resources Investigations of the U.S. Geological Survey*, Book 3, Chapter A8. U.S. Geological Survey.

Talley, J. H., and R. H. Simmons. 1988. Inland Bays low-flow monitoring, July 1985–September 1988. Unpublished report prepared for Delaware Department of Natural Resources and Environmental Control.



## LITTLE ASSAWOMAN BAY BOTTOM SEDIMENT CHARACTERISTICS

*by Evelyn M. Maurmeyer*

Bottom sediment samples were collected from Little Assawoman Bay in June 1991 to characterize the sediment distribution pattern within the bay. Samples were obtained from 35 stations using a pole-mounted coring device which penetrated the upper 20 cm of the substrate. Sediments were visually examined and classified on the basis of grain size. Water depths also were measured at each station.

A map depicting bottom sediment characteristics of Little Assawoman Bay is shown in Figure 1. Bottom sediments in the eastern portion of the bay generally consist of medium- to fine-grained gray sand. The deeper central portion of the bay is characterized by dark gray to black silty to clayey sediments, which continue toward the western shore of the bay. Little Bay, an embayment of the northern part of Little Assawoman Bay, shows a similar bottom sediment pattern, with sand on the east, and silt/clay in the central and western sections. The Narrows, a channel connecting Little Assawoman Bay with Little Bay, contains medium sand. Bottom sediments of the tidal tributaries, Dirickson Creek and Miller Creek, consist of dark gray clay. Bottom sediments in Assawoman Canal consist of sandy silty clay, and the artificial canals at South Bethany are underlain by sand.

Bottom sediments in Little Assawoman Bay appear to correlate with water depth and distance from the shoreline, and reflect present and past physical processes of sedimentation within the various sections of the bay. Bottom sediments in the eastern section of the bay, located in shallow water (<1 m), generally consist of well-sorted sand, characteristic of relict flood tidal delta/overwash sediments derived from the adjacent coastal barrier. Sand content diminishes, and silt/clay content increases in the deeper open waters of the central bay. Bottom sediments along the western section of the bay reflect the low-energy estuarine conditions and also appear to correlate with shoreline characteristics. Constricted channels, such as the Narrows, are underlain by sand due to relatively high flow velocities. Low-energy natural tidal creeks are characterized by muddy substrates, and bottom sediments of artificial waterways (Assawoman Canal and South Bethany canals) exhibit the characteristics of the substrate into which these waterways were excavated.

Future work should involve a more extensive and detailed sampling grid, quantitative size analysis of bottom sediment samples, and a coring study to document the vertical changes in sedimentary sequences, in order to interpret the geological history of Little Assawoman Bay.

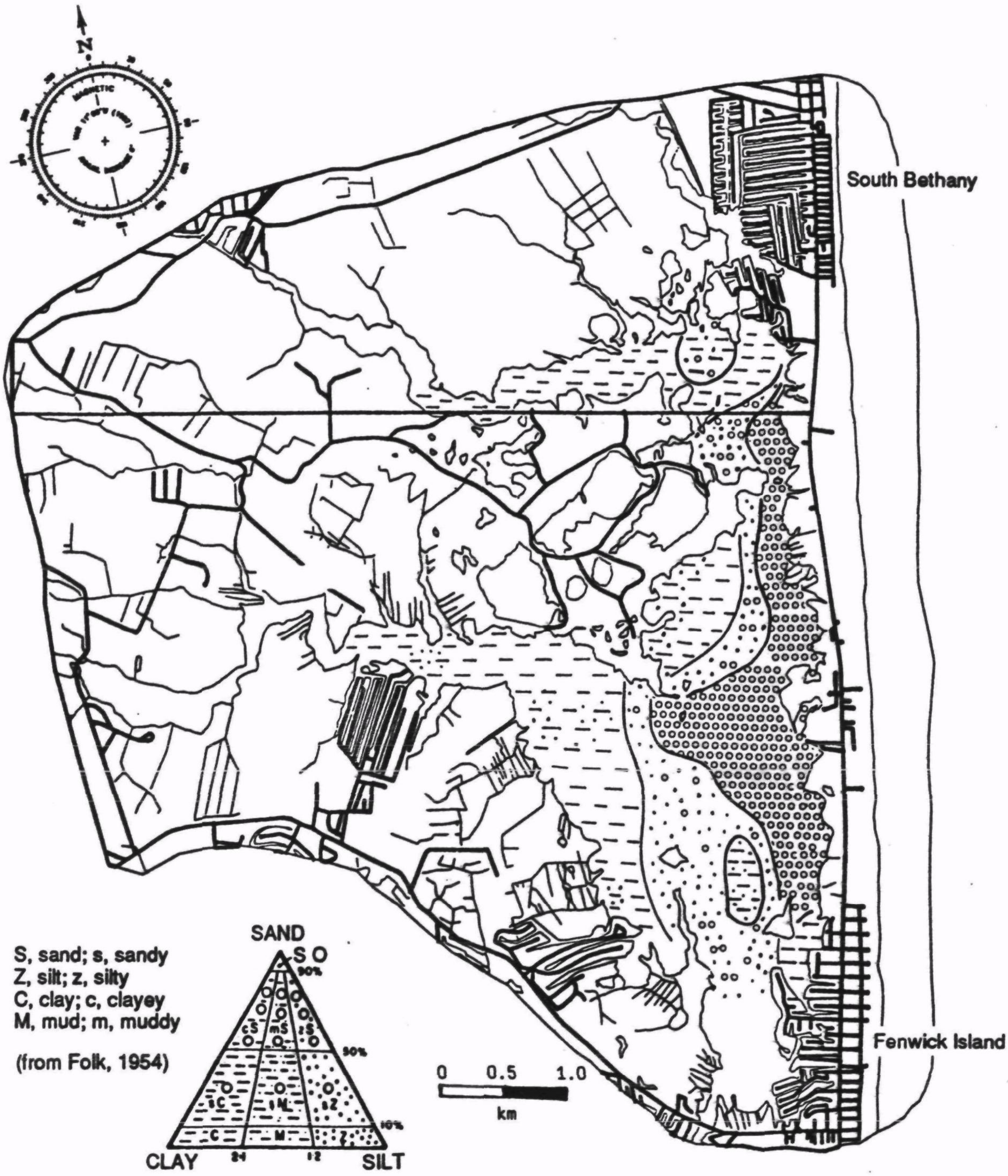



**Figure 1. Bottom Sediment Characteristics, Little Assawoman Bay, Delaware.**

# NUTRIENTS IN DIRECT GROUNDWATER DISCHARGE TO LITTLE ASSAWOMAN BAY, DELAWARE

*by Judith M. Denver and Deborah A. Bringman*

The potential for significant contributions of nitrogen species and phosphorus to Little Assawoman Bay by direct groundwater discharge through bay-bottom sediments was indicated by a limited survey conducted on June 12, 1991, at three shoreline locations. The difference in hydraulic head between groundwater and overlying surface water was measured, and samples of groundwater were collected using a mini-piezometer (a small-diameter well point with a 3-centimeter-long screened interval) connected to a peristaltic pump and a manometer.

Samples of water in bay-bottom sediments were collected about 1 meter offshore at depths from 0.5 meters and 1.0 meters below the sediment-water interface. Measurements of salinity, pH, and head difference were made on site, and nutrient analyses were performed in the laboratory (see Table 1). Bottom sediments at Sites 1, 2, and 3, where samples were collected, consisted of permeable sand and gravel, whereas sediments at site 4, where samples could not be collected, were predominantly fine-grained silt and clay (Figure 1).

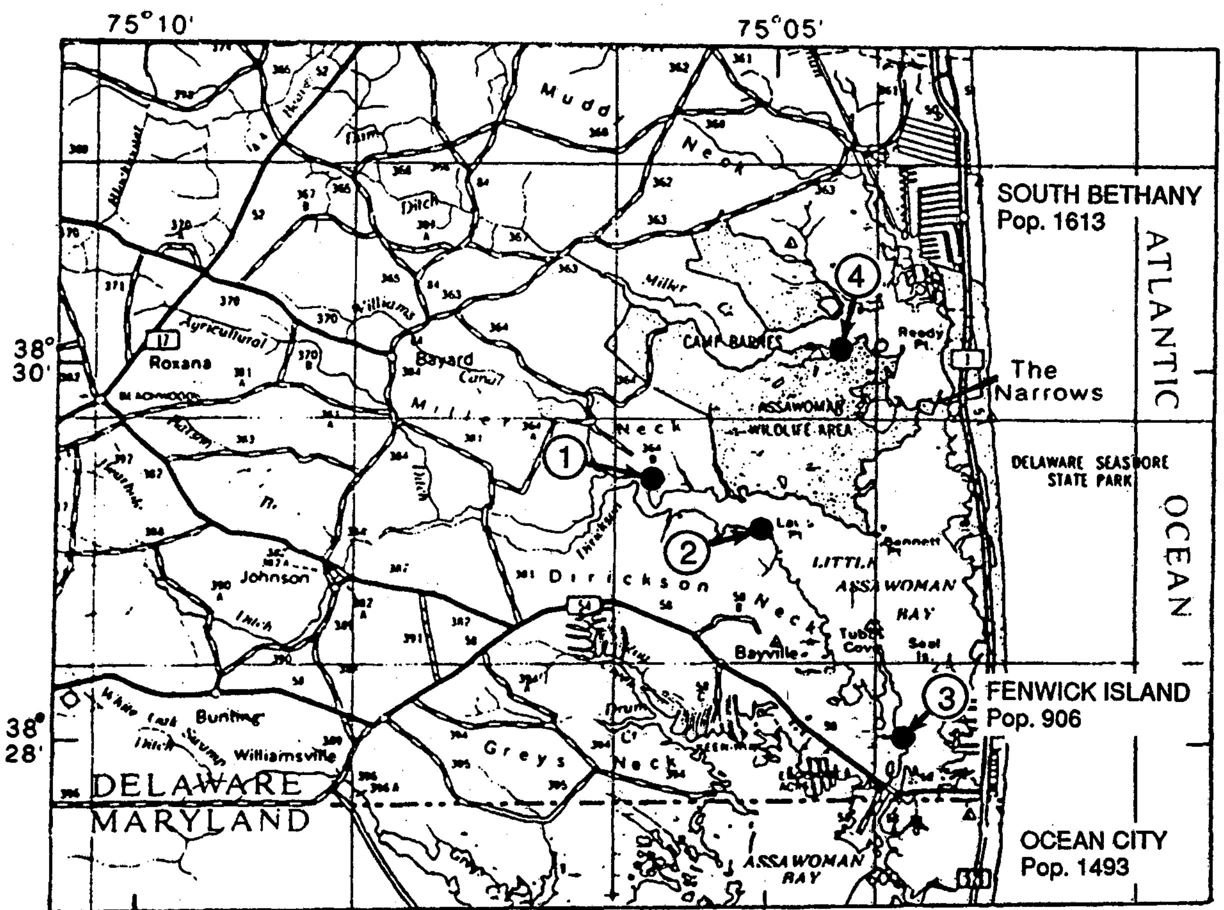
Salinities in the groundwater (0.52–5.1 ppt) were significantly lower than those in the bay water (14.0–27.0 ppt), indicating the presence of fresher groundwater beneath the saline water in the bay. Hydraulic head differences indicated an upward head gradient at Site 1 and a downward head gradient at Sites 2 and 3 (see table). The measurements were made close to high tide (approximately 12:15 p.m. at the Narrows, according to Rob Gano, Delaware Department of Natural Resources and Environmental Control, oral communication, July 22, 1991). Because the estimated tidal amplitude in the bay (15–33 cm) is greater than the downward hydraulic-head differences measured, it is likely that groundwater at each site discharges to the bay during part of each tidal cycle.

Most of the area around Little Assawoman Bay contains poorly drained soils and anoxic groundwater. Therefore, the discharge of anoxic groundwater to the bay could be greater than the discharge of oxic groundwater. Nitrogen speciation depends on redox conditions in the aquifer and bay-bottom sediments. Anoxic conditions were indicated at Sites 1 and 2 by the relatively high concentrations of ammonia, which is a reduced nitrogen species, compared to nitrate, which is an oxidized-nitrogen species. In contrast, oxic conditions were indicated at Site 3 because of the relatively high concentration of nitrate compared to ammonia (see table). Concentrations of phosphorus were higher in groundwater from the anoxic sites than in groundwater from the oxic site. These results suggest that groundwater sources of nitrogen species and phosphorus could be important in the nutrient dynamics of Little Assawoman Bay and point out the need for additional research in this area.

| *Site* | *Time* | *Δh* (cm) | *Salinity* (ppt) | *Nitrate* (μM) | *Ammonia* (μM) | *Phosphate* (μM) | *Silica* (μM) |
|---|---|---|---|---|---|---|---|
| 1 | 1000 | +2.4 | 5.1 | 0.34 | 160.0 | 1.01 | 65.3 |
| 2 | 1100 | -10.7 | 3.6 | 0 | 32.2 | 1.45 | 51.3 |
| 3 | 1200 | -14.6 | 0.52 | 431.0 | 1.39 | 0.17 | 125.0 |

**Table 1. Results of Groundwater Measurement and Sampling, 12 June 1991.**

$\Delta h$ = hydraulic head difference; + indicates groundwater head greater than surface-water head; - indicates surface-water head greater than groundwater head; ppt = parts per thousand; μM = micromoles per liter; cm =centimeter.




Base from Delaware Department of Transportation
Sussex County highway map. 1:126,720

●1 Sampling site and site number

0 1 2 MILES
0 1 2 KILOMETERS

## LITTLE ASSAWOMAN BAY SHORELINE CHARACTERISTICS

*by Wendy Carey and Maria Sadler*

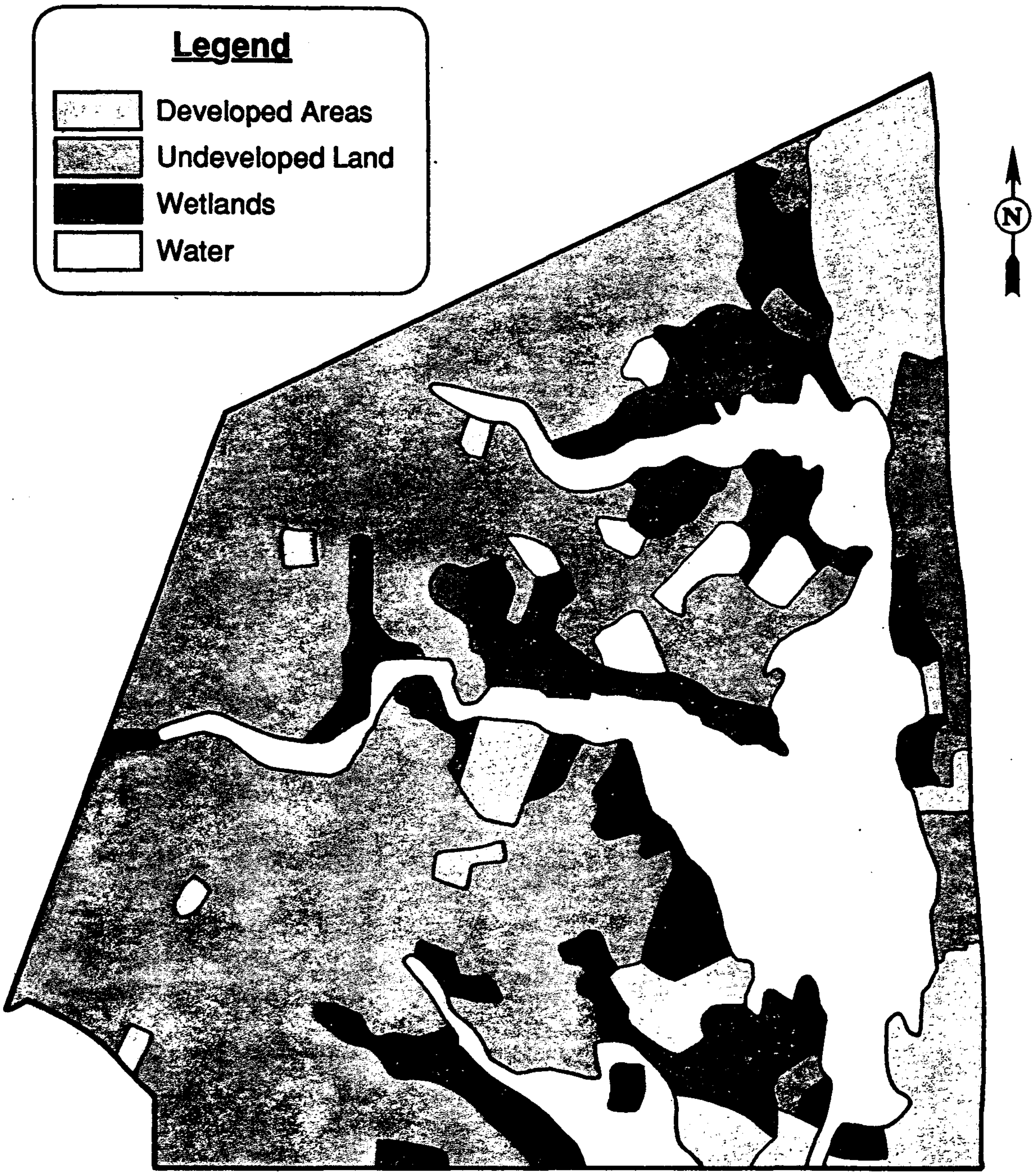
A perimeter survey of Little Assawoman Bay was conducted in June 1991 to determine shoreline characteristics. Field observations regarding shoreline type were made from a small boat and recorded on a base map. Verification of field data was accomplished using a planimeter, USDA aerial photographs (1"=660' scale), and National Wetlands Inventory maps.

Results from the on-site field inspection and qualitative analysis of aerial photos indicate that the low-energy, transgressive shoreline of Little Assawoman Bay can be divided into three major geomorphic types: (1) irregular marsh shoreline, (2) sandy pocket beaches, and (3) artificial stabilization structures such as rubble and bulkheads. These comprise approximately 79%, 4%, and 17% of the linear shoreline, respectively. The marsh shoreline along Little Assawoman Bay is characterized by broad emergent wetlands which have developed on topographically low areas along the western shore and on relict flood tidal deltas/overwash fans in eastern sections. More narrow wetlands fringes are found along headlands such as Laws Point. Typical wetlands vegetation includes both low-marsh species, such as *Spartina alterniflora*, and high-marsh species, such as *Spartina patens*, *Distichlis spicata*, *Baccharis halimifolia*, *Iva frutescens*, and *Phragmites australis*. The bayward edge of the marsh appears to be erosional and is typified by a dense mat of sediment, peat, and roots, usually in the form of an undercut and/or vertical scarp.

Sandy beaches comprise only 4% of the Little Assawoman Bay shoreline and are typically narrow pocket beaches between crenulate marsh shoreline. Narrow, bluffed sandy beaches may be found in areas where headlands intersect the bay, as in the vicinity of Strawberry Landing and Drum Point. Eroding pre-Holocene headlands such as Miller Neck and Dirickson Neck provide a source of sandy material for the pocket beaches on the western bay shoreline. Pocket beaches along the eastern side of Little Assawoman Bay are supplied by sand from the Atlantic coast, transported across the narrow coastal barrier during storm and/or overwash episodes.

Approximately 17% of the Little Assawoman Bay shoreline consists of bulkheads and other artificial stabilization structures. Many developments in the area include dead-end lagoon systems with as many as 12 bulkheaded lagoons per developed area. A notable amount of rubble has been dumped along a section of southern shoreline, from Drum Point to Point of Ridge. Continued developmental pressure will likely result in additional man-made structures along the bay shoreline.

The geographic location of each of these three environments is dependent on geologic history, coastal processes, and human developmental pressures. Future research should include analyses of both long-term (sea-level rise) and short-term (wave, wind, storm) processes on shoreline evolution. Additional data on natural processes and historical erosion rates would result in a comprehensive determination of erosion-prone areas of the bay.




**Map of General Shoreline Characteristics, Little Assawoman Bay, Delaware.** Shorelines designated as "Developed Areas" are typically characterized by stabilization structures such as rubble and bulkheads; "Wetlands" areas are dominated by *Spartina alterniflora* and *Spartina patens* tidal marshes; "Undeveloped Land" includes agricultural areas, forested uplands, beaches, and associated back-barrier environments. Small pocket beaches along the Little Assawoman Bay shoreline are not depicted at this scale. (Map provided by Delaware Department of Natural Resources and Environmental Control.)

# NUTRIENT SURVEY OF LITTLE ASSAWOMAN BAY

*by Susan Welch, Lisa Graziano, Bruce Overman, Til Purnell, and William Ullman*

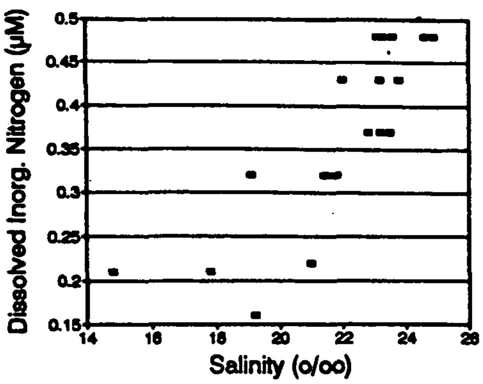
Twenty-one surface water samples were collected from the "navigable" waters of Little Bay and Little Assawoman Bay on June 12, 1991. Temperature, salinity, acidity, and secchi disk depth were determined. Water samples were collected, filtered, and stored for the subsequent determination of dissolved nitrate ($NO_3^-$), nitrite ($NO_2^-$), ammonium ($NH_4^+$), phosphate ($PO_4^{3-}$), and silica ($H_4SiO_4$). Samples were also collected for the determination of particulate phosphorus and chlorophyll *a*.

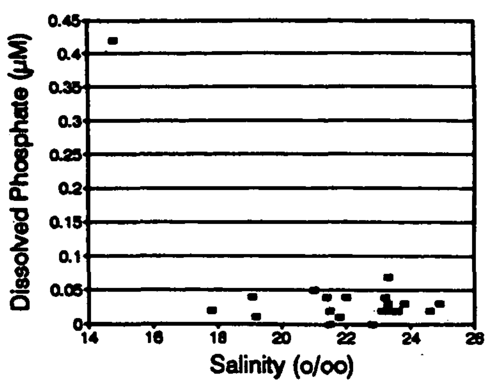
The results of this survey are displayed as property versus salinity plots in Figure 1. There was very little variation in the salinity of Little Bay and Little Assawoman Bay waters. The total range found was between 14 and 27 ppt. The observed salinities are a reflection of the lack of rainfall and therefore surface water runoff into the bays during the few weeks preceding sampling.

$NO_3^-$ concentrations were highest in the more saline waters, those coming from Big Assawoman Bay having the highest concentration. This result is at odds with observations made in both Indian River and Rehoboth bays, where the highest nitrogen concentrations are always found in the freshest waters. It is not clear, on the basis of this single day of sampling, whether the Big Assawoman Bay is a nitrogen source or sink for Little Assawoman Bay on an annual basis or whether the low level of nitrogen is a characteristic of the Little Assawoman Bay lagoonal system. Our studies of Indian River and Rehoboth bays indicate that the coastal ocean may be a nutrient source during the summer when nutrients are otherwise depleted.

The concentrations of all nitrogen species were extremely low. $NH_4^+$ concentrations were consistently below detection ($^{\sim}$0.05 µM). The levels of DIN (= $NO_3^- + NO_2^- + NH_4^+$) are as low as the lowest levels we have previously measured elsewhere in the Inland Bays (central Rehoboth Bay, 17 July 1990). They appear to reflect, as in the previous observations of the Rehoboth Bay lagoon, the efficient utilization of nitrogen within the lagoon and the lack of significant external fluxes to the bay during the summer. Based on our studies of Rehoboth Bay, we would conclude that the present observations reflect an aspect of the seasonal cycle of nitrogen fluxes and utilization and are not representative of the concentrations throughout the year.

The sample taken from upper Dirickson Creek (Sample 1) had anomalously high $H_4SiO_4$, $NO_2^-$, $PO_4^{3-}$, and chlorophyll *a* concentrations. The nutrient levels may have resulted from a recent resuspension of the bottom sediment (as by a boat) or an anomalous plume of water from a salt-marsh creek. The high chlorophyll levels that co-occurred with these relatively high nutrient levels suggest that where nutrients are more available, more primary production is possible. On the basis of this data set alone, however, it is impossible to determine which nutrient or other factor limits productivity.


Dissolved Inorg. Nitrogen (µM)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
14 16 18 20 22 24 26
Salinity (o/oo)


Dissolved Phosphate (µM)
0.45
0.4
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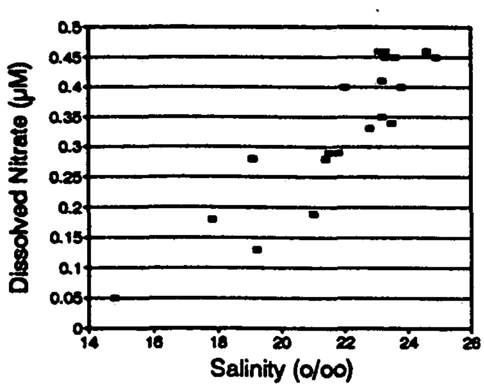
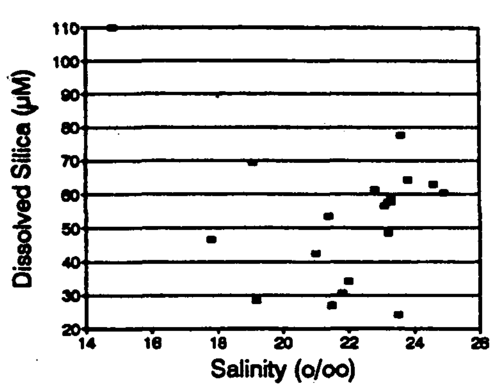
0.3
0.25
0.2
0.15
0.1
0.05
0
14 16 18 20 22 24 26
Salinity (o/oo)


Dissolved Nitrate (µM)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
14 16 18 20 22 24 26
Salinity (o/oo)


Dissolved Silica (µM)
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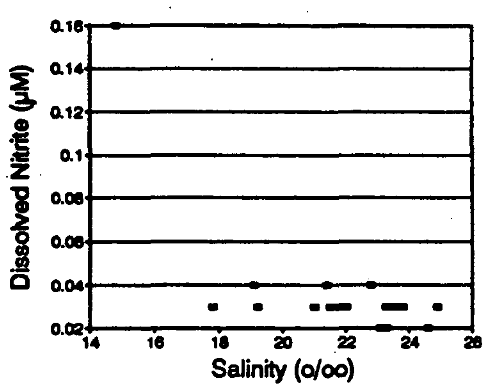
100
90
80
70
60
50
40
30
20
14 16 18 20 22 24 26
Salinity (o/oo)


Dissolved Nitrite (µM)
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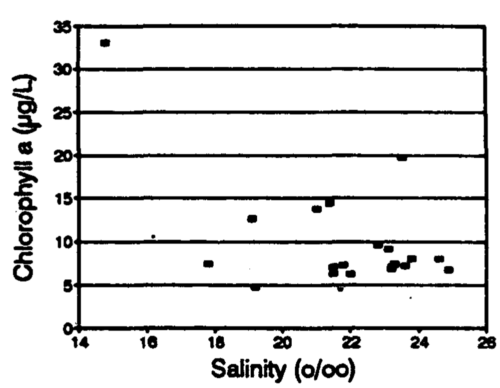
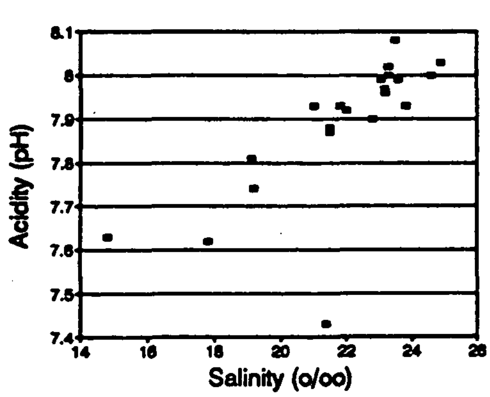
0.14
0.12
0.1
0.08
0.06
0.04
0.02
14 16 18 20 22 24 26
Salinity (o/oo)


Chlorophyll a (µg/L)
35
30
25
20
15
10
5
0
14 16 18 20 22 24 26
Salinity (o/oo)


Acidity (pH)
8.1
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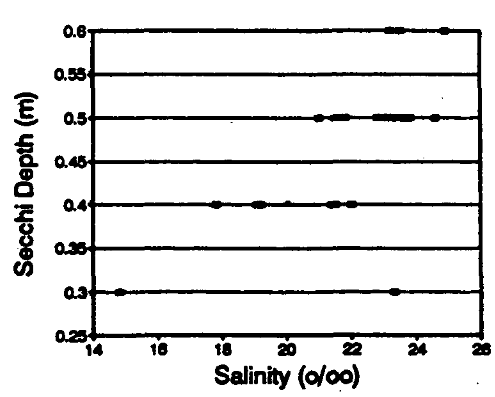
7.9
7.8
7.7
7.6
7.5
7.4
14 16 18 20 22 24 26
Salinity (o/oo)


Secchi Depth (m)
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
14 16 18 20 22 24 26
Salinity (o/oo)

## LIGHT/DARK BOTTLE STUDIES AND LIGHT EXTINCTION MEASUREMENTS IN LITTLE ASSAWOMAN BAY

*by John F. Davis*

Light- and dark bottle incubations of ambient water from Little Assawoman Bay were conducted at Mulberry Landing pier on June 12, 1991, to estimate gross photosynthesis rates and respiration rates due to phytoplankton growth in the water column. The technical background, procedures, and calculations are illustrated in Thomann and Mueller (pp. 284–291).

In conjunction with the light/dark bottle studies, the light extinction characteristics of the water column were investigated by measuring the Photosynthetically Active Radiation (PAR) with a submersible quantum meter (Licor) at several depths through the water column. Light extinction coefficients were determined, as presented in Thomann and Mueller (pp. 420–422).

Four sets of light/dark bottles were incubated at 1 to 2 foot depths. Each bottle was incubated for approximately two to three hours, spanning from 11:30 a.m. to 3:30 p.m. Net photosynthesis rates ranged from 0.36 mg/l/hr to 0.55 mg/l/hr, with an average of 0.42 mg/l/hr. Gross photosynthesis rates ranged from 0.29 mg/l/hr to 0.59 mg/l/hr, with an average of 0.42 mg/l/hr. Respiration rates ranged from 0 mg/l/hr (undetectable) to 0.11 mg/l/hr, with an average of 0.03 mg/l/hr.

Calculations were conducted to extrapolate the measured photosynthesis and respiration rates (as discussed above) to average daily rates and areal rates (expressed in terms of grams of DO per square meter per day—gm/m$^2$/day). The daily average gross photosynthesis rate was estimated as 5.4 mg/l/day, or 5.4 gm/m$^2$/day assuming an average depth of 1.0 meter in the bay. The average daily respiration rate was estimated as 1.8 mg/l/day, or 1.8 gm/m$^2$/day assuming a depth of 1.0 meter. Based on these calculations, the P/R ratio was 3.0, which indicates that photosynthetic production of dissolved oxygen outweighed the consumption of dissolved oxygen by algal respiration on this day.

Light extinction coefficients ranged from 2.0 per meter (1/m) to 4.9 per meter, with an average of 2.9 per meter. The depth of penetration of one percent of PAR ranged from 0.9 to 2.3 meters.

### References

Thomann and Mueller. 1987. *Principles of Surface Water Quality Modeling and Control.* New York: Harper and Row.

## Little Assawoman Bay Light-Dark Bottle Study

| Bottle Number | L-1 | D-1 | L-2 | D-2 | L-3 | D-3 | L-4 | D-4 |
|---|---|---|---|---|---|---|---|---|
| Depth (ft) | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 |
| Salinity (ppt) | 26 | 26 | 26 | 26 | 26.3 | 26.3 | 26.3 | 26.3 |
| Avg Temp (°C) | 25.5 | 25.5 | 25.5 | 25.5 | 26 | 26 | 26 | 26 |
| AVG PAR (μmol/m²/sec) | 325 | 325 | 183 | 183 | 303 | 303 | 303 | 303 |
| Total Time (hr) | 2 | 2.25 | 2.5 | 2.83 | 2 | 2.25 | 2.5 | 2.75 |
| Initial DO (mg/l) | 5.9 | 5.9 | 5.9 | 5.9 | 6.2 | 6.2 | 6.2 | 6.2 |
| Final DO (mg/l) | 7 | 5.8 | 6.8 | 5.6 | 7 | 6.3 | 7.1 | 6.4 |
| Calculations | | | | | | | | |
| R (mg/l/hr) | | 0.044 | | 0.106 | | -0.04 | | -0.07 |
| $P_{net}$ (mg/l/hr) | 0.55 | | 0.36 | | 0.4 | | 0.36 | |
| $P_g$ (mg/l/hr) | 0.594 | | 0.466 | | 0.356 | | 0.287 | |

## Calculation of Daily Photosynthesis and Respiration Rates

Avg Max $P_g$ rate = 0.53 mg/l/hr
Avg Daily Rate (based on 16 hr photoperiod (Tp), and sin function):
$P_g = P_{max}(2/3.1416)Tp$ $P_g$= 5.399 mg/l/day
Avg Daily Photosynthesis Based on avg depth = 1 meter (approx 3.3ft):
$P_g$ = 5.398 mg/l/d * 1 m = 5.4 gm/m²/day
Avg Respiration Rate = .075 mg/l/hr = 1.80 mg/l/day = 1.8 gm/m²/day assuming 1 meter depth
P/R ratio = 3.0

## Light Extinction Measurements

| Time | 11:30 | 12:00 | 12:00 | 13:00 | 13:30 | 14:30 |
|---|---|---|---|---|---|---|
| Depth (M) | PAR | PAR | PAR | PAR | PAR | PAR |
| 0 | 1500 | 1200 | 1200 | 1100 | 1100 | 608 |
| 0.01 | | 445 | 445 | 660 | 565 | 210 |
| 0.2 | 330 | 275 | 355 | 490 | 320 | 116 |
| 0.3 | | 225 | 260 | 380 | 250 | 67 |
| 0.4 | 150 | 200 | 200 | 306 | 215 | 49 |
| 0.6 | 83 | 105 | 115 | 180 | 105 | 27 |
| 0.7 | 64 | 103 | 99 | 160 | 75 | |

## Calculation of Extinction Coefficient ($K_e$): $I=I_o(\exp-K_e*z)$

| Time | 11:30 | 12:00 | 12:00 | 13:00 | 13:30 | 14:30 |
|---|---|---|---|---|---|---|
| $K_e$ (1/m) | 4.9 | 2.2 | 2.1 | 2 | 2.8 | 3.5 |
| Z(1%) m | 0.9408 | 2.095 | 2.195 | 2.305 | 1.6464 | 1.317 |

# DISTRIBUTION OF CHLOROPHYLL A, DISSOLVED AND PARTICULATE PHOSPHATE IN LITTLE ASSAWOMAN BAY

*by Lisa Graziano, Bruce Overman, and Richard Geider*

Samples were collected from 21 stations in Little Assawoman Bay on June 12, 1991, for the determination of chlorophyll *a*, and particulate and dissolved phosphate concentrations. In the mid-bay, dissolved phosphate concentrations were ≤0.05 at all stations, while particulate phosphate levels were higher (20–30 μM). A slight positive co-variation was observed. Particulate phosphate also co-varied with chlorophyll at the mid-bay stations. Secchi disk measurements showed little variation in water turbidity in the bay and no correlation with particulate phosphate or chlorophyll *a*.

Dirickson Creek was sampled at the head, the mouth, and two points of intermediate salinity. Particulate phosphate, dissolved phosphate, and chlorophyll *a* concentrations increased with increasing distance from the mouth of the creek and show a good apparent correlation with one another. All three were associated with turbidity, as can be seen in the plots of chlorophyll *a* and particulate phosphate versus secchi disk depth. Dirickson Creek therefore appears to be a source of fresh water and of dissolved inorganic phosphate.

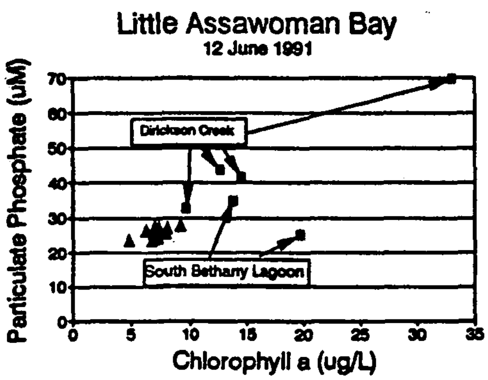
Miller Creek, which discharges into Little Bay, was sampled at three stations along a slight salinity gradient. No change in chlorophyll *a*, particulate phosphate, or dissolved phosphate with salinity was observed in this creek. The minimum secchi disk depth was 0.4 meters, which is greater than that observed at the end of Dirickson Creek. At the time of sampling, there appeared to be no net inflow of freshwater from the creek.

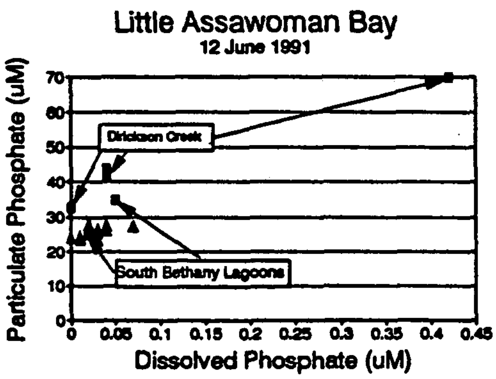
Two samples were taken at the ends of the South Bethany Lagoons and indicate conditions different from Dirickson Creek. The water was relatively clear and had only slightly elevated particulate and dissolved phosphate levels, but did have a high chlorophyll *a* concentration. This particular area is deeper and less well-mixed by wind than Dirickson creek; particulate phosphate seemed to be associated with turbidity while chlorophyll *a* was not.

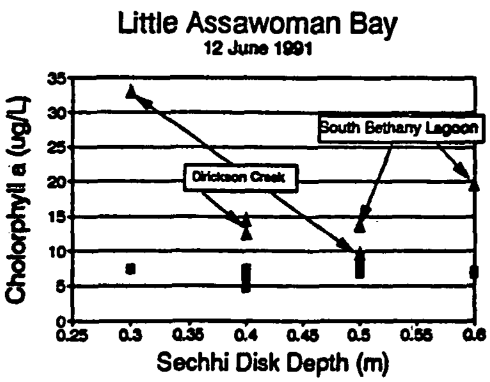
Except for Dirickson Creek, Little Assawoman Bay was fairly uniform in regard to salinity, chlorophyll *a*, and particulate and dissolved phosphate concentrations. This is in contrast to Rehoboth and Indian River bays, where there is greater freshwater input and a range of concentrations is observed. For example, chlorophyll *a* concentration in Indian River Bay in June ranged from 0.33 μg/L to 96.8 μg/L, and salinity varied from near 0 to 25.0 ppt. Another difference is the number of point source inputs of phosphate. Several industries as well as sewage treatment plants are sources of both nitrate and phosphate in the two larger bays. With the exception of Dirickson Creek, no major point source of phosphate was apparent in Little Assawoman Bay.

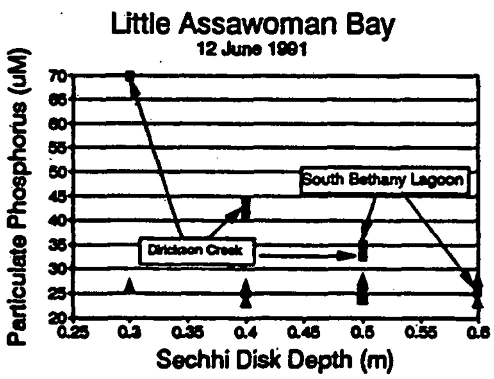
**Table 1. Temperature, Salinity, and pH at 21 Stations in Little Assawoman Bay, 12 June 1991.**

| Station | Temp (°C) | ppt | pH |
|---|---|---|---|
| 1 end of Dirickson Creek | 24.8 | 14.8 | 7.63 |
| 2 mouth of trailer park, Swan Key | 24.3 | 19.1 | 7.81 |
| 3 end of Swan Key- lagoon near houses | 24.4 | 21.4 | 7.43 |
| 4 between Mulberry Landing and Laws Pnt. | 24.3 | 22.8 | 7.90 |
| 5 between Pnt Cedars Isl and Coach Pnt. | 24.3 | 23.6 | 7.99 |
| 6 East fork of Tubbs Cove | 24.0 | 23.8 | 7.93 |
| 7 Pt. of Cedars Isl - Barrier Island | 24.3 | 23.2 | 7.97 |
| 8 bridge at Fenwick Isl | 24.3 | 24.9 | 8.03 |
| 9 Old Inlet and Drum Pnt. | 24.2 | 24.6 | 8.00 |
| 10 by the 'N' in Assowoman on the map | 24.6 | 23.1 | 7.99 |
| 11 off Pepper's Landing | 23.9 | 23.3 | 8.02 |
| 12 pilings at North end of bay | 24.9 | 23.2 | 7.96 |
| 13 the Narrows | 24.8 | 23.3 | 8.00 |
| 14 Reedy Point | 25.0 | 22.0 | 7.92 |
| 15 Strawberry Point | 25.5 | 21.8 | 7.93 |
| 16 off Long Point- Camp Barnes | 27.5 | 17.8 | 7.62 |
| 17 off Horse Point | 27.0 | 19.2 | 7.74 |
| 18 mouth of Canal | 28.0 | 21.5 | 7.87 |
| 19 off Canal Pond | 26.4 | 21.5 | 7.88 |
| 20 end of lagoon off W. Canal | 28.0 | 23.5 | 8.08 |
| 21 end of lagoon near road (Sth Bethany) | 29.0 | 21.0 | 7.93 |



# A HYDROGRAPHIC SURVEY OF LITTLE ASSAWOMAN BAY

*by Greg Lambert*

A hydrographic survey was performed on June 12, 1991, along east-west transects across Little Assawoman Bay. At specified stations, temperature, salinity, acidity (pH), and dissolved oxygen concentration were determined. The locations of stations are given in Figure 1 and the results of this survey are given in Table 1.

There is little variation in temperature, pH, and salinity across the bay, indicating that Little Assawoman Bay should be described hydrographically as a lagoon rather that as a estuary. Lagoons are characterized by little or no freshwater input. Although there is little evidence of seawater dilution by fresh water at the time of sampling, it is possible that more estuarine conditions apply at other times. In this case, the bay would more correctly be described as an estuarine lagoon.

A comparison of dissolved oxygen concentrations with turbidity as measured with a secchi disk, indicates that the highest turbidity is associated with the highest oxygen concentrations (see Figure 2). Since resuspension of bottom sediments often leads to a consumption of dissolved oxygen, this result suggests that a large fraction of the turbidity in Little Assawoman Bay is due to biologically active phytoplankton.

There is also a co-variance of dissolved oxygen concentration with the time of sampling. In the course of the day, dissolved oxygen concentrations increased at the rate of $0.495 \pm 0.095$ mL/L/hr. Assuming no exchange with the atmosphere over this time period and that the net rate of production is constant over the whole bay depth and whole depth of light penetration (0.4 m secchi disk depth) over an eight-hour daylight period, this is equivalent to a net rate of daylight productivity of $0.78 \pm 0.15$ g C/m$^2$/day. Due to the assumptions made, this is a minimum estimate of the net primary production in Little Assawoman Bay.

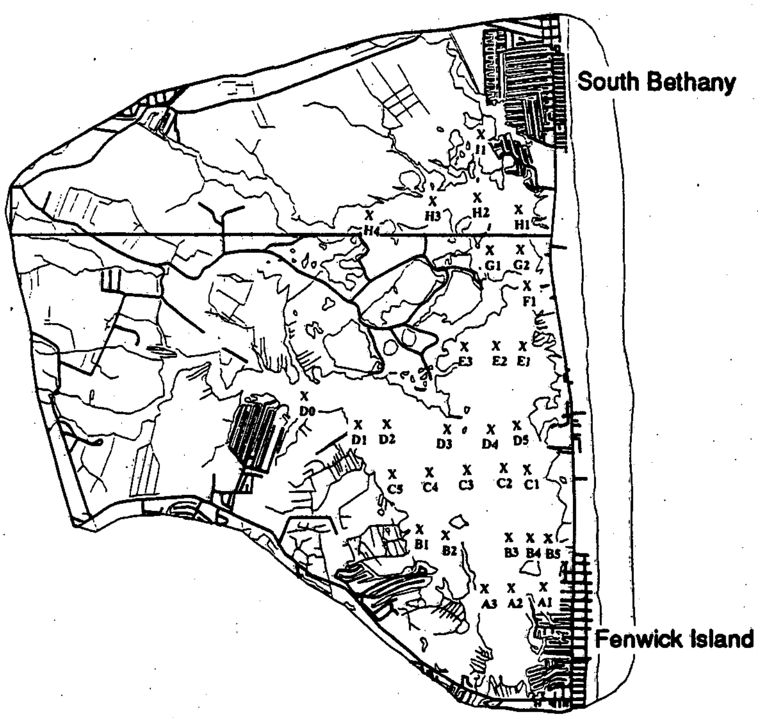
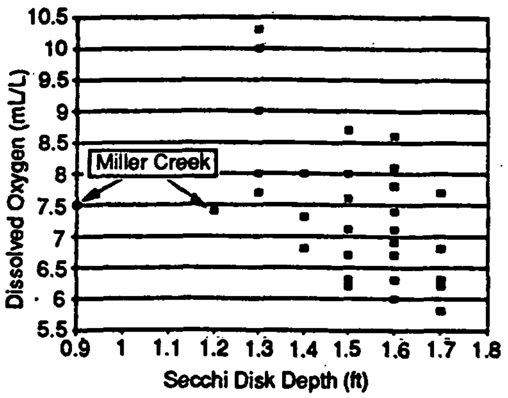



**Figure 1. Locations for Hydrographic Survey, Little Assawoman Bay, Delaware.**

Hydrographic surveys are needed at other times of the year to determine the correct hydrographic classification of Little Assawoman Bay and to correctly determine the average net primary productivity of the bay.

**Table 1. Hydrographic Survey Results, Little Assawoman Bay, 12 June 1991.**

| Station | Temperature (°C) | pH | Dissolved Oxygen (mL/L) | Salinity (‰) |
|---|---|---|---|---|
| A1 | 24.1 | 7.9 | 6.2 | 25.5 |
| A2 | 24.2 | 7.9 | 6.3 | 25.7 |
| A3 | 24.3 | 8.0 | 6.3 | 25.4 |
| B1 | 24.3 | 7.9 | 6.0 | 24.7 |
| B2 | 24.3 | 7.9 | 6.3 | 24.6 |
| B3 | 24.3 | 8.0 | 6.7 | 25.2 |
| B4 | 24.2 | 8.0 | 6.8 | 25.3 |
| B5 | 23.8 | 8.0 | 7.1 | 25.6 |
| C1 | 24.2 | 8.1 | 7.7 | 24.5 |
| C2 | 24.3 | 8.1 | 7.4 | 24.5 |
| C3 | 24.5 | 8.0 | 6.7 | 24.4 |
| C4 | 24.5 | 8.0 | 7.4 | 24.1 |
| C5 | 24.7 | 8.1 | 7.5 | 24.5 |
| D0 | 26.2 | 8.2 | 9.0 | 23.2 |
| D1 | 24.8 | 8.0 | 6.9 | 24.7 |
| D2 | 25.1 | 8.0 | 6.2 | 23.7 |
| D3 | 25.0 | 8.0 | 5.8 | 23.6 |
| D4 | 24.9 | 8.0 | 6.3 | 24.3 |
| D5 | 24.9 | 8.0 | 8.6 | 24.5 |
| E1 | 24.8 | 8.1 | 8.7 | 24.6 |
| E2 | 25.0 | 8.1 | 7.4 | 24.0 |
| E3 | 25.2 | 8.1 | 7.4 | 23.8 |
| F1 | 25.1 | 8.1 | 7.8 | 24.0 |
| G1 | 25.4 | 8.1 | 8.1 | 24.3 |
| G2 | 25.5 | 8.1 | 8.0 | 24.3 |
| H1 | 25.4 | 8.0 | 7.6 | 23.6 |
| H2 | 25.1 | 8.0 | 7.7 | 23.4 |
| H3 | 25.8 | 8.0 | 7.5 | 23.4 |
| H4 | 26.1 | 8.0 | 7.4 | 22.5 |
| I1 | 25.8 | 8.0 | 7.3 | 23.9 |
| J1 | 26.8 | 8.2 | 10.0 | 24.1 |
| J2 | 26.1 | 8.0 | 8.0 | 24.0 |
| K1 | 26.9 | 8.2 | 10.3 | 24.1 |
| K2 | 25.8 | 8.0 | 8.0 | 24.1 |



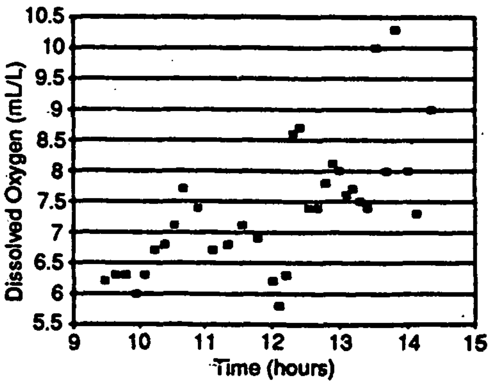




**Figure 2. Dissolved Oxygen Concentrations As Compared with Turbidity, Little Assawoman Bay, 12 June 1991.**

## THE BENTHOS OF LITTLE ASSAWOMAN BAY

*by Michael Bock, Susan Laessig, and Doug Miller*

The benthos of Little Assawoman Bay and Little Bay were sampled using a benthic grab sampler. The grab sampler was lowered to the bottom and a 4 cm x 6 cm x 4 cm deep sample was taken. Two grabs were taken at each station. In total, 14 stations were sampled. The samples were field-sieved in 1 mm sieves and preserved in formaldehyde. The specimens were identified in the laboratory using Watling and Maurer's *Guide to the Macroscopic Estuarine and Marine Invertebrates of the Delaware Bay Region* (1973).

The samples revealed that the species abundances in the two bays were relatively low. The dominant taxa was polychaetes (Phylum Annelida), with the most abundant species being the bamboo worm, *Clymenella torquata*. This organism was found in most habitats occurring in the bay. The only non-polychaete groups were Nematoda and Rhynchoceala. Small arthropods were conspicuous by their absence; no arthropods were found in any of the grabs. No live mollusks were found, but a small number of empty shells were found.

There was also a spatial trend within the bays. In the upper bays, nearest to the points of freshwater input, very few specimens were found. In these areas, the sediment was a fine clay. In the mid-bay region, diversity was relatively high, generally the highest in the bay. Here the sediment was a fine sand. In the fore-bay region, closest to Fenwick Island, diversity was moderate. Here the sediment was a medium sand. The exception to this trend was the Assawoman Canal. In the canal, the diversity was high, whereas in Little Bay, proper diversity was low. This could be due to the flow of water through the canal.

The patterns of species abundance could be caused by the physical nature of the bay. Little Assawoman Bay is very shallow; its depth rarely exceeds 2 meters. In addition, it has no direct connection to the ocean, and so the water chemistry of the bay should be closely coupled to run-off. This would create a highly variable and stressful environment. In addition, the opportunities for external recruitment would be low. Only those species capable of withstanding these variations would survive, and the introduction of new species would be limited. These variations would be more pronounced in the upper bay region and thus account for the low species abundance in these areas.

In order to truly assess the state of the benthic ecosystem in Little Assawoman Bay, we must collect more data. It is important to verify the observed spatial trends and to measure seasonal trends. It is also important to determine the underlying reasons for the observed trend in species abundance. The hypotheses put forth above should be expanded and tested.

Station 1: 38°29.1'N 75°05.55'W, Dirickson Creek, Time 0905 EDT, 2 grabs, 6ft, fine clay, no organisms

Station 2: 38°28.77'N 75°04.57'W, Peppers Landing, Time 0930 EDT, 2 grabs, 6.5ft, fine clay, no organisms

Station 3: 38°28.35'N 75°04.35'W, Point of Cedars Island, Time 0935 EDT, 2 grabs, 4 ft, medium sand

Organisms: Unidentified polychaete A (Hereafter denoted UNK A) 1*

Station 4: 38°27.80'N 75°03.65'W, Drum Point, Time 0955 EDT, 2 grabs, 5.5 ft, fine sand

| | | | | |
|---|---|---|---|---|
| Organisms: | Polychaete | Onuphidae | *Diopatra cuprea* | 1 |
| | Polychaete | Chaetopteridae | *Spiochaetopterus oculatus* | 2 |
| | Polychaete | Maldanidae | *Clymenella torquata* | 12 |
| | UNK A | | | 5 |

Station 5: 38°28.23'N 75°03.23'W, Fenwick Island St. Pk., Time 1010 EDT, 2 grabs, 2 ft, medium sand

| | | | | |
|---|---|---|---|---|
| Organisms: | Polychaete | Maldanidae | *Clymenella torquata* | 1 |

Station 6: 38°28.45'N 75°03.58'W, Fenwick Island State Park, Time 1035 EDT, 2 grabs, 6 ft, fine clay

| | | | | |
|---|---|---|---|---|
| Organisms: | Polychaete | Maldanidae | *Clymenella torquata* | 5 |

Station 7: 38°28.84'N 75°04.05'W, Bennett Point, Time 1055 EDT, 2 grabs, 5.5 ft, fine sand

| | | | | |
|---|---|---|---|---|
| Organisms: | Polychaete | Maldanidae | *Clymenella torquata* | 14 |
| | UNK A | | | 5 |

Station 8: 38°30.31'N 75°03.90'W, Little Bay, Time 1115 EDT, 2 grabs, 3 ft, clay

| | | | | |
|---|---|---|---|---|
| Organisms: | Polychaete | Maldanidae | *Clymenella torquata* | 3 |

Station 9: 38°30.43'N 75°03.94'W, Assawoman Canal, Time 1125 EDT, 2 grabs, 4 ft, med-fine sand

| | | | | |
|---|---|---|---|---|
| Organisms: | small nematodes (3mm) | | | 2 |
| | Polychaete | Onuphidae | *Diopatra cuprea* | 1 |
| | Polychaete | Nephyidae | *Nephtys bucera* | 2 |
| | UNK A | | | 1 |

Station 10: 38°30.18'N 75°04.66'W, Strawberry Landing, Time 1135 EDT, 2 grabs, 4 ft, fine mud, no organisms

Station 11: 38°29.29'N 75°04.27'W, off Tonys Pond, Time 1205 EDT, 2 grabs, 5 ft, clay

| | | | | |
|---|---|---|---|---|
| Organisms: | Rhynchoceala | | *Tubulanus pellucidus* | 1 |
| | Polychaete | Maldanidae | *Clymenella torquata* | 2 |

Station 12: 38°28.86'N 75°03.55'W, Daisy Marsh, Time 1215 EDT, 2 grabs, 4.5 ft, medium sand

| | | | | |
|---|---|---|---|---|
| Organisms: | Polychaete | Nereidae | *Nereis succinae* | 1 |
| | Polychaete | Maldanidae | *Clymenella torquata* | 32 |
| | UNK A | | | 1 |

Station 13: 38°28.79'N 75°04.14'W, Cherrybush Island, Time 1240 EDT, 2 grabs, 6 ft, fine mud

| | | | | |
|---|---|---|---|---|
| Organisms: | Polychaete | Maldanidae | *Clymenella torquata* | 3 |

Station 14: 38°28.96'N 75°04.80'W, Mulberry Landing, Time 1250 EDT, 2 grabs, 5 ft, fine mud, no organisms

*To convert from the number of organisms found per station to abundances in individuals per $m^2$ multiply by 208.

## LITTLE ASSAWOMAN BAY SEINING SURVEY

*by Kent S. Price and John Schneider*

On June 12, 1991, we undertook a survey at five collecting sites in Little Assawoman Bay using a 10-meter-long x 1.2-meter-deep hand seine with a chain lead line and a 1.2 x 1.2-meter pocket. The seine was constructed of 1/4" stretched delta nylon mesh and was hauled approximately 30–35 meters in one tow at each station.

Little Assawoman Bay appears to be a thriving nursery for the blue crab *(Callinectes sapidus)*, the spot *(Leiostomus xanthurus)*, and the summer flounder *(Paralichthys dentatus)*—three important commercial and recreational species (Table 1).

Some stations differed in their species composition as was to be expected. Muddy areas tend to support the mummichog (*F. heteroclitus*) and the glass shrimp (*Palaemonetes* sp.) while the striped killifish (*F. majalis*) tends toward sandy bottoms, and the striped mullet (*Mugil cephalus)* was found only in a blind canal (Tables 1 and 2).

The composition of the fish fauna is quite similar to that demonstrated in studies conducted by Derickson and Price (Trans. Amer. Fish Sec. 1973, #3) in Indian River and Rehoboth bays 20 years ago with these exceptions. Only a dozen species were collected today compared to over 40 in the original study. This result is most likely due to sampling frequency in that 20 monthly collections from 18 stations in Indian River and Rehoboth bays from June 1968 to April 1970 yielded 41,286 fishes representing 46 species.

In the original study, the following five species, listed in order of abundance, comprised 89% of the catch: *Fundulus majalis*, *Menidia menidia*, *Fundulus heteroclitus*, *Pseudopleuronectes americanus* (winter flounder), and *Anchoa mitchilli* (bay anchovy). The latter two species are conspicuously absent from today's survey but the spot seems to be more abundant than before. The winter flounder seems to have suffered a long-term climate-related decline. However, the winter flounder was captured at two of six deep-water locations sampled with a beam trawl on June 12, 1991, mostly in the sandy area of the lower bay (T. Lankford, personal communication). The bay anchovy represented only 4.35% of the total catch in the original survey and may be rare enough to have been missed by our gear. The fish fauna in Little Assawoman Bay appears to be as healthy as in either of the other two bays based on the Derickson and Price (1973) study. More current data is needed in all three bays to verify that assumption.

The relative abundance of blue crabs and forage species suggests that Little Assawoman Bay is in a reasonably healthy state. This conclusion, however, is based only on this cursory study. More sampling is needed to verify this conclusion.

| TABLE 1: | (Strawberry Landing) | | (Sassafras Landing) | | (Bayview) | | (Sail Boat Rental) | | (Blind Canal) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | # | MS(mm) | # | MS(mm) | # | MS(mm) | # | MS(mm) | # | MS(mm) |
| Callinectes sapidus<br>Blue Crab | 46 | 50.9 | 32 | 32.6 | 139 | 47.7 | 28 | 33.7 | 41 | 38.5 |
| Fundulus heteroclitus<br>Mummichog | 170 | 75.0 | 93 | 65.8 | 36 | 69.7 | 21 | 66.0 | | |
| Fundulus majalis<br>Striped killifish | 14 | 102.1 | 4 | 95.0 | | | 14 | 102.1 | | |
| Leiostomus xanthurus<br>Spot | 60 | 56.1 | 8 | 50.5 | 9 | 65.0 | 35 | 72.5 | 6 | 73.8 |
| Menidia menidia<br>Atlantic silversides | 626 | 33.8 | 463 | 45.0 | 138 | 92.3 | 80 | 62.5 | 80 | 46.8 |
| Palaemontes sp<br>Glass shrimp | 20 | 10.1 | 22 | 11.4 | | | 5 | 10. | 187 | 10.6 |
| Trinectes maculatus<br>Hogchoker | 1 | 61.0 | | | | | | | | |
| Strongylura marina<br>Atlantic needlefish | 1 | 105.0 | | | | | 1 | 43.0 | 3 | 82.0 |
| Paralichthyes dentatus<br>Summer flounder | | | 1 | 82.0 | 11 | 90.0 | 4 | 71.0 | 1 | 96.0 |
| Gobiosoma bosci<br>Goby | | | 1 | 55.0 | | | | | | |
| Synodus foetens<br>Lizard fish | | | | | | | 1 | 43.0 | | |
| Cyprinodon variegatus<br>Sheephead minnow | | | | | | | 1 | 52.0 | | |
| Sphoeroides pachygaster<br>Blunthead puffer | | | | | | | 1 | 32.0 | 1 | 34.0 |
| Mugil cephalus<br>Striped mullet | | | | | | | | | 82 | 63.0 |

MS = Mean Size; Total Length for fish; carapace width for crabs.

**TABLE 2:**

| Station # and Time | Location (Bottom Type) | $H_2O$ Depth (cm) | Secchi Depth (cm) | Salinity (°/₀₀) | $H_2O$ Temp (°C) | Air Temp (°C) |
|---|---|---|---|---|---|---|
| 1 (0930) | Strawberry Landing (Sandy Mud) | 20-40 | 45 | 26 | 25.0 | 27.0 |
| 2 (1005) | Sassafras Landing (Muddy Sand) | 20-45 | 45 | 25 | 25.0 | 27.0 |
| 3 (1050) | Bayview Park at Andrew Street (Sand and eroded marsh mud) | 40-60 | 48 | 27 | 24.5 | 29.0 |
| 4 (1140) | Sail Boat Rental off Rt 1 South (Sandy) | 20-55 | 50 | 30 | 26.0 | 29.5 |
| 5 (1245) | Corner of Dagsboro St and Shultz in Blind Canal (Muddy Sand) | 30-70 | 58 | 29 | 26.0 | 29.5 |

## JUVENILE FISH SURVEY

*by Daniel Martin, T. Lankford, and Timothy Targett*

Shallow bays and estuaries are important nursery grounds for juvenile fishes; roughly three-quarters of western Atlantic marine fishes of commercial and sport value spend some part of their lives in these habitats. Our survey of Little Assawoman Bay was designed to determine what role, if any, the bay plays in the life cycle of marine fishes.

Juvenile ichthyofauna were sampled in the deeper reaches of Little Assawoman Bay using a new (to us) beam trawl. The trawl is designed around a modified epibenthic sled frame, 1 m wide x 0.2 m high at the mouth, to which the sides and upper edge of a net (1-cm stretch mesh) are attached. The lower lip of the net is recessed 1 meter in a 'v' shape, and lead-lined. Ideally, benthic organisms are disturbed by the lead line, but retained by the side and top net panels.

The fish and crab catches from six tows are given by station in Table 1, and the corresponding transects are shown in Figure 1. Physical data collected at the beginning of each trawl are given separately in Table 2.

Although only a meager 'snap-shot' of the demersal ichthyofauna was taken, Little Assawoman Bay does indeed appear to function as a nursery ground for juvenile fishes in much the same manner as its larger sister bays. Our data are not quantitative, however, as sampling efficiency probably varied due to variable towing speeds within and between trawls (i.e., adjustments were made as we became familiar with the new gear).

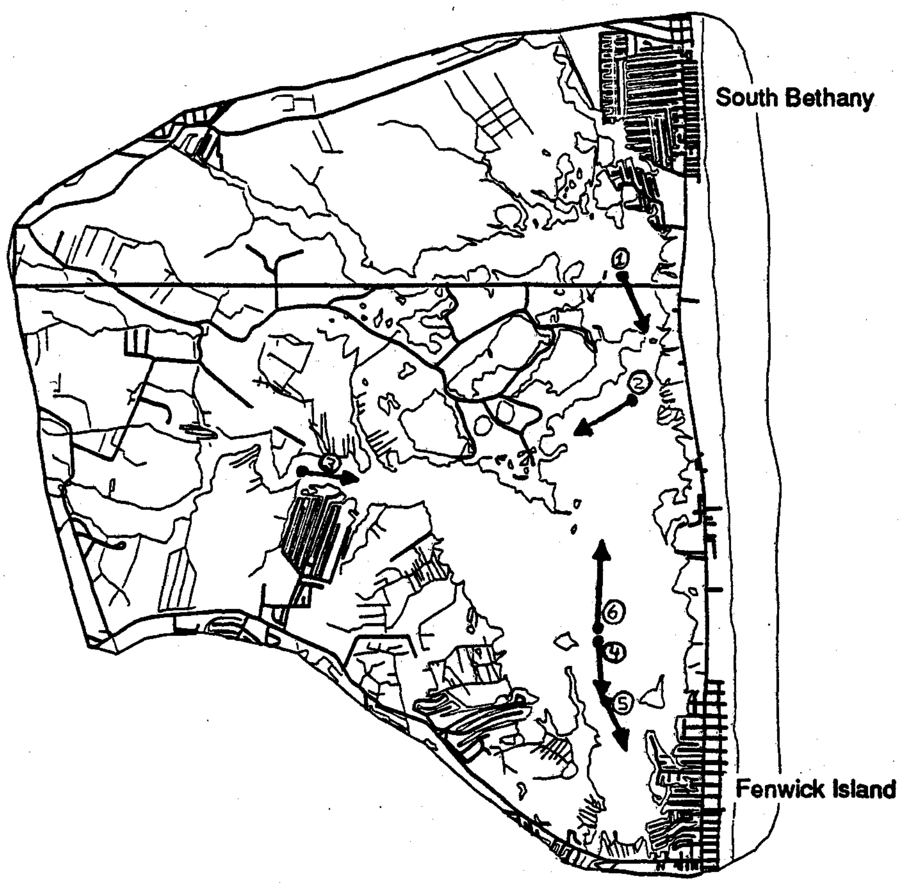
Table 1. Species Collected, Trawling Survey, Little Assawoman Bay.

| Station No. | Species Present (fish and blue crab) | No. of Each Species | Standard Lengths (mm) (CW = carapace width, mm) |
|---|---|---|---|
| 1 | *Callinectes sapidus*<br>*Leiostomus xanthurus* | 1<br>1 | <br>41 |
| 2 | *Leiostomus xanthurus*<br>*Callinectes sapidus* | 3<br>4 | 96,37,28 |
| 3 | — | — | — |
| 4 | *Callinectes sapidus* | 2 | (CW approx. 30-60) |
| 5 | *Psuedopleuronectes americanus*<br>*Paralichthys dentatus*<br>*Callinectes sapidus* | 4<br>2<br>16 | 59,55,55,54<br>71,67<br>(CW approx. 30-60) |
| 6 | *Pseudopleuronectes americanus*<br>*Paralichthys dentatus*<br>*Leiostomus xanthurus*<br>*Trinectes maculatus*<br>*Micropogonias undulatus*<br>*Callinectes sapidus* | 2<br>4<br>5<br>1<br>1<br>187 | 61,56<br>79,73,72,65<br>96,94,90,39,38<br>102<br>82<br>(CW approx. 30-150) |

**Table 2. Trawling Survey Transects.**

| Sta. No. | Trawl Start & End | Air (°C) | $H_20$ (°C) | Water Depth (m) | Sal. (ppt) | Secchi Depth (m) | Notes on bottom type, etc. |
|---|---|---|---|---|---|---|---|
| 1 | 1015:00<br>1018:30 | 23 | 24 | 0.6 | 25 | 0.6 | fine sand, many polychaetes |
| 2 | 1058:00<br>1103:00 | 23.5 | 23 | 1.0 | 26 | 0.6 | fine sand bottom stabilized by worm tubes |
| 3 | 1142:00<br>1145:30 | 26 | 24 | 1.2 | 26 | 0.6 | clay with some silt |
| 4 | 1221:00<br>1229:00 | 26 | 24 | 1.4 | 27 | 0.6 | muddy sand |
| 5 | 1303:00<br>1315:00 | 24.5 | 25 | 1.3 | 29 | 0.6 | fine sand with some mud |
| 6 | 1329:00<br>1341:00 | -- | -- | -- | -- | -- | -- |

**Figure 1. Trawling Locations, Little Assawoman Bay, 12 June 1991.**



## EPIBENTHIC INVERTEBRATE SURVEY OF LITTLE ASSAWOMAN BAY

*by Bennett Anderson*

There is little information concerning the distribution of non-commercial benthic invertebrates in the Little Assawoman Bay system. The success of recruitment, survival, and reproduction of benthic invertebrates is dependent on a wide range of environmental parameters. As such, the distribution of benthic invertebrates is of particular value in the characterization of stressed coastal marine environments.

Five samples of benthic fauna were collected from the deepest areas of Little Assawoman Bay (Figure 1). A 1-meter beam trawl was towed for approximately 10 minutes at each site. The beam trawl is designed to collect epibenthic species and infauna living within 2 cm of the sediment water interface. Only individuals greater than 1 cm in size are quantitatively retained in the trawl. A 225 $cm^2$ box core was used to sample burrowing infauna at one station.

Two species dominate the epibenthic community in Little Assawoman Bay: the blue crab *(Callinectes sapidus)* and the glassy bubble shell gastropod *(Haminoea solitaria)*. The numbers found at each station are given in Table 1. The blue crab population density appeared to be highest in the deepest waters of the bay, which are also those where the sediment is coarsest (> 90% sand). The glassy bubble shell gastropod was found primarily in the eastern zone of Little Assawoman Bay and was most abundant in muddy and silty sandy sediments.

The blue crab is an important commercial and recreational species in Delaware and elsewhere along the eastern coast of the United States. At the time of sampling, a large number of crab pots were deployed in Little Assawoman Bay, and crabbers were abundant at Mulberry Landing. Apparently, the local human population is aware of the crab population.

*Haminoea solitaria* is a small tectibranch snail. Its shell is thin and fragile and may range in color from bluish white to brownish. It is a common species in muddy bays and well-sheltered areas along the East Coast of the United States south of Cape Cod. It has no commercial value.

No epibenthic algae were recovered with the beam trawl during this survey. This result was unexpected as epibenthic algae are abundant in many regions of Indian River and Rehoboth bays throughout the year. The difference may be due to the very high turbidity (secchi disk depth $\leq$ 0.6m) in Little Assawoman Bay as compared to the other bays.

One small box core was recovered from the muddy sediments of Station 3, Dirickson Creek. Although the organisms in this sample were neither identified nor counted, it appears that there is a dense and diverse infaunal community dominated by bivalves and polychaetes in the muddy areas of Little Assawoman Bay. These results must be confirmed with further sampling.

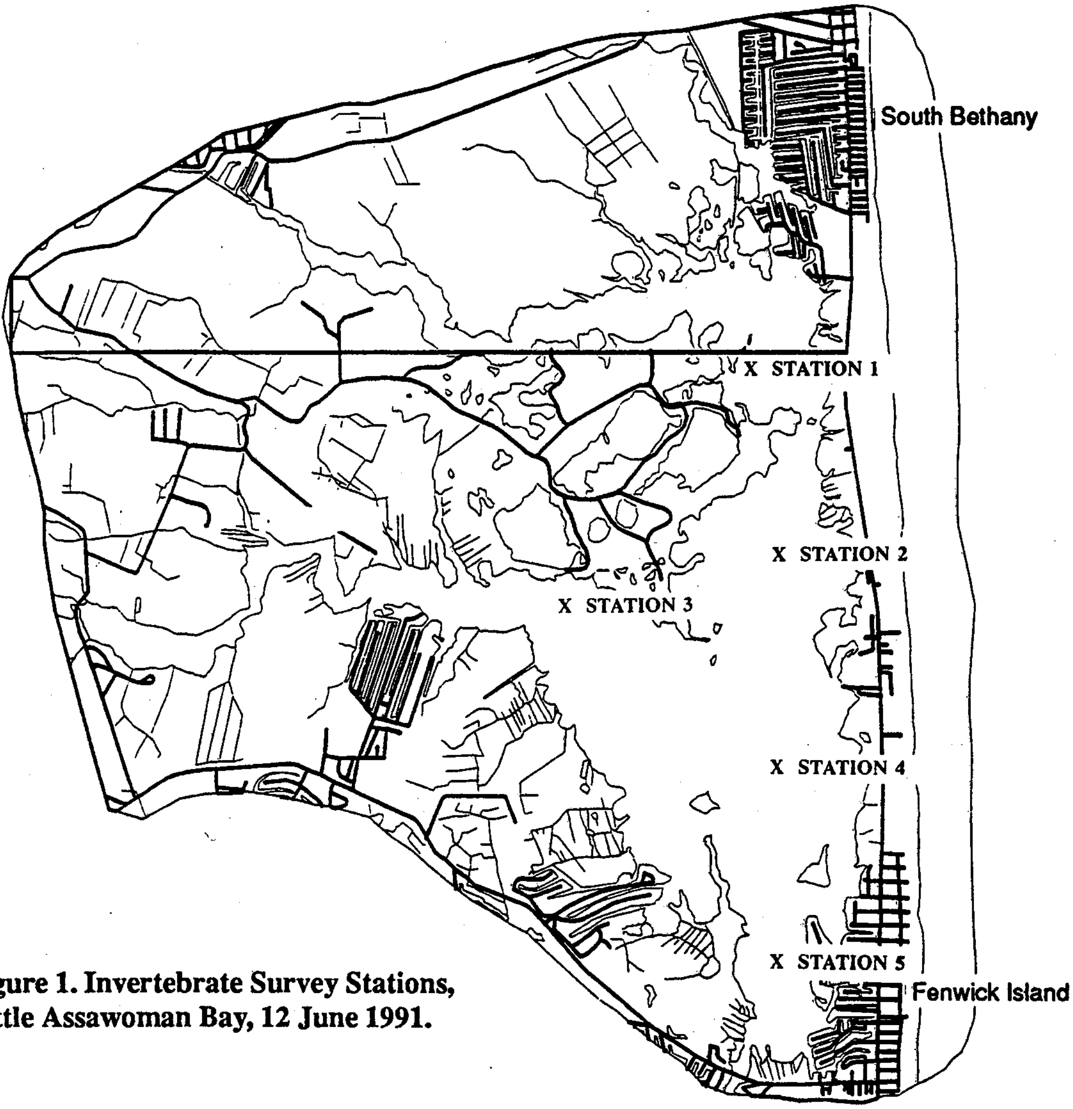



**Figure 1. Invertebrate Survey Stations, Little Assawoman Bay, 12 June 1991.**

| | Station 1 | Station 2 | Station 3 | Station 4 | Station 5 |
|---|---|---|---|---|---|
| *Callinectes sapidus* | Not found | 3 | 1 | 187 | 16 |
| *Haminoea solitaria* | Not found | Not found | 28 | 17 | Too Numerous To Count |

**Table 1. Dominant Benthic Species, Little Assawoman Bay.**

## PRELIMINARY HARD CLAM AND MACROBENTHIC ALGAE SURVEY OF LITTLE ASSAWOMAN BAY

*by Jeff Tinsman*

An important hard clam *(Mercenaria mercenaria)* resource has existed in Indian River and Rehoboth bays since the stabilization of Indian River Inlet. This resource is the basis of both an active commercial and recreational fishery in the Inland Bays. Surveys of hard clam distributions in Indian River and Rehoboth bays were conducted by Humphries and Daiber (1967), Cole and Spence (1977), and the EPA (1987). These surveys provide a useful data set on the basis of which the status and trends of the hard clam population can be determined. Despite occasional reports of isolated hard clam populations in Little Assawoman Bay, no systematic survey has ever been conducted.

A preliminary assessment of hard clam densities was undertaken on June 12, 1991. A total of 13 stations (Figure 1) were sampled using a commercial bull rake at most stations. At the shallow stations (2, 4, and 11), a recreational clam rake was used. Although the purpose of the survey was to determine hard clam populations, the sampling gear also is appropriate for making a qualitative assessment of macrobenthic algae. Macrobenthic algae are common in parts of Rehoboth Bay.

No live mollusks were collected during this sampling effort although old clam shells, soft clam shells, and oyster shells were recovered at some stations. At the time of sampling, the salinity exceeded 20 ppt—the minimum salinity needed to support a successful hard clam population—everywhere in Little Assawoman Bay. Based on previous surveys and anecdotal evidence, these high salinities are anomalous. During periods of high freshwater runoff, the average salinity in Little Assawoman Bay may drop substantially below that needed to sustain the hard clam. Salinities less than 20 ppt may be sustained for extended periods of time.

No macrobenthic algae were collected at any site in the Bay. This result was a major surprise since, at this time of year, the sea lettuce, *Ulva*, would be commonly found in many areas of Indian River and Rehoboth bays. More extensive sampling over the whole seasonal cycle will be necessary to explain the absence of macrobenthic algae in Little Assawoman Bay.

### References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Humphries, E., and F. C. Daiber. 1967. Shellfish survey of Indian River Bay and Rehoboth Bay, Delaware. Technical Report. Narragansett, Rhode Island: Northeast Maine Health Sciences Laboratory, Public Health Service.

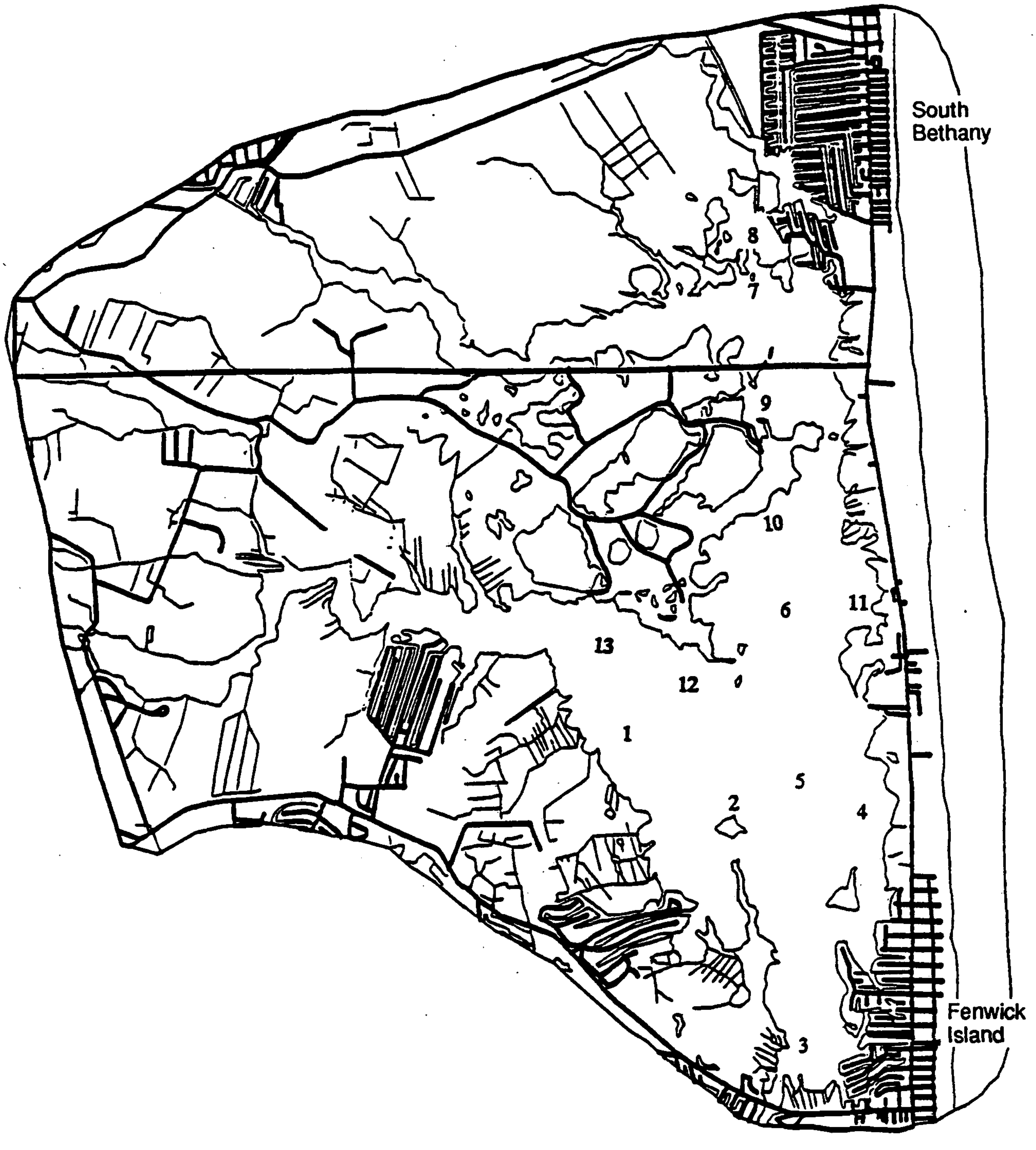



Figure 1. Hard Clam and Macrobenthic Algae Survey Locations, Little Assawoman Bay.

## ASSAWOMAN WILDLIFE AREA: A DESCRIPTION OF ITS HISTORY AND PRESENT USE

*by Robert D. Gano, Jr.*

Little Assawoman Bay and its tributaries, Miller and Dirickson creeks, have relatively less shoreline development and more public land than the other Inland Bays. At least 50% of the surface area of Miller Neck, the peninsula between Miller and Dirickson Creeks, consists of Assawoman Wildlife Area (AWA). Fenwick Island State Park shares jurisdiction of lands on the barrier island (east of Route 1). A brief description of AWA and the management program may help characterize public land use within the Little Assawoman Bay watershed.

The AWA was established from farms lost during the Great Depression. The U.S. Department of Agriculture and the Forest Service took title to the eight farms (35–303 acres) from 1936–1942. The Delaware Board of Fish and Game Commissioners agreed to a 99-year lease in 1943 to manage the area for the "purpose of wildlife, recreation, and forest management." Camp Barnes was established as a youth summer camp in 1949 by the Delaware Association of Police Chiefs. In 1954, the land was sold to the State of Delaware. Pavilions built at Strawberry and Mulberry Landing in 1935–36 were included in the sale.

The AWA is comprised of three disjunct, but contiguous parcels of land—Miller Neck (1335.5 acres), Muddy Neck (284 acres), and the Beach (75.8 acres). The AWA is 49% forested (828 acres) with a sweet gum *(Liquidambar styraciflua)*-loblolly pine *(Pinus taeda)* association. Six slightly brackish (0–24 ppt salinity) impoundments totaling 264 acres account for 16% of the area. Salt marsh (primarily *Spartina patens* and *Distichlis spicata*) comprises 20% of the acreage (332 acres). Agricultural fields used as wildlife food and cover plots account for 85 acres (5%).

Numerous (15) ephemeral ponds (in varied degrees of wetness) (35 acres-2%) contain rare and endangered plant species. The discovery of a seasonally flooded woodland pond or Delmarva Bay containing at least nine rare plant species, including three federal candidates for endangered species listing, prompted the purchase of an additional 227 acres in July 1989. Other rare plant species have subsequently been discovered on other parts of the area.

The wildlife area is managed primarily for waterfowl, white-tailed deer, northern bobwhites, and mourning doves. Free public hunting from 16 waterfowl blinds and 40 deer stands is provided under a special permit hunt. The fishing areas (Mulberry, Strawberry, and Sassafras landings) receive heavy use (no utilization data available) for crabbing, boating, and picnicking. Reptiles and amphibians receive special protection particularly within the freshwater ponds containing rare plant species and the freshwater impoundments. A mammal on the state endangered list, the Delmarva fox squirrel *(Sciurus cinereus nigra)*, was reintroduced in 1984 with a release of 13 individuals. Surveys indicate some reproductive success, but population status is uncertain. Squirrel hunting has been closed since 1984.

The impoundments are managed to improve migratory and wintering waterfowl habitat and to enhance water bird feeding habitat. With the installation of two wells and pumps with a total capacity of 390 gallons per minute in 1990, the two largest impoundments are actively managed for waterfowl food and cover—salt-marsh bulrush (*Scirpus robustus*), dwarf spike rush *(Eleocharis parvula)*, and Walter's millet *(Echinochloa walterii)*. A third of the wildlife area is set aside as refuge where no human activity is permitted.

Fields of corn, dwarf sorghum, soybean, and clover are planted within the refuge for waterfowl. Outside the refuge is a mixture of soybean, buckwheat, German millet, and sorghum in small plots. Larger fields managed for mourning dove hunting are planted in sunflower, corn, and winter wheat. All fields are limed and fertilized in accordance with a soil sample recommendation from the University of Delaware, although since the crops are not harvested, yearly fertilizer inputs are minimal.

A wildlife management plan describing the area, the fauna, and management techniques is available from the Wildlife Section of the Delaware Division of Fish and Wildlife, Delaware Department of Natural Resources and Environmental Control.

# LITTLE ASSAWOMAN BAY
# FIELD CHARACTERIZATION OF RECREATIONAL USE

*by Jim Falk and Alan Graefe*

We traveled around the perimeter of Little Assawoman Bay to inspect recreational facilities and uses. There is intense residential development in the South Bethany area and in Fenwick Island. Residential canal developments are evident in both locations. There is light tourism development (commercial/retail trade) in the South Bethany area and heavier tourism development on Fenwick Island.

There was very little recreational activity observed on the bay during the morning hours. Two or three small outboards were observed, as well as two pontoon boats passing the Route 54 bridge between 11:30 a.m. and noon. We also noticed some crabbing activity from the bay shoreline (five people) and three boats fishing near the Route 54 bridge at 12:20 p.m. Additional boating activity started to pick up around 1:00 p.m.

A major part of characterizing recreational uses included counting boats at docks in canal developments on the bay (see map for site locations). We observed that a majority of docks in the canals were unoccupied and many boats were not yet in the water (but they were on-site on trailers).

Bill Hamilton of the B-R Bait and Tackle Shop (York Beach Mall–South Bethany) stated that 75% of bay use is crabbing; there are no clams in the bay; that many boats never leave their docks; and fishing is poor in this area. Better fishing is found farther south.

We stopped at the Fenwick Island State Park concession stand that rents sailboats, jet skis, and sailboards. No boats had been rented by 10:45 a.m. when we arrived. The attendants told us, however, that it had been very busy the previous day.

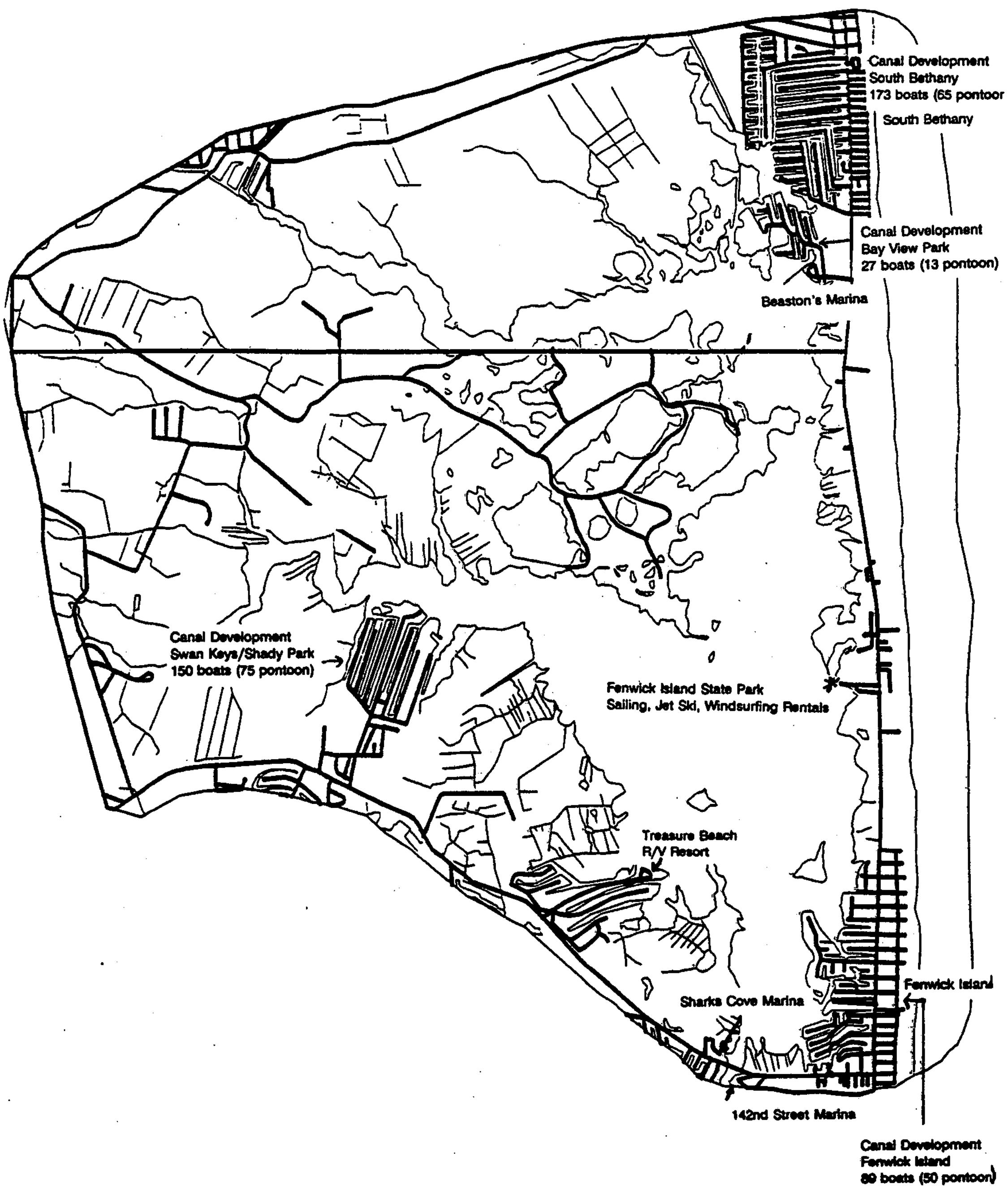
We talked with Brelle Beaston at Beaston's Marina in Bay View Park (South Bethany). It is a small marina with 20 slips. There were six pontoon boats, two sailboats, and four powerboats in the water. She confirmed that most of the activity in the bay is recreational crabbing, with some water sports (jet skiing and wind surfing), but not much fishing.

We counted the boats at the 142nd Street Marina. There were 23 boats in the water. Eleven of the boats were pontoon boats and there were 11 empty slips. We also talked to the attendant in charge of rental boats at the facility. They had 16 to 20 boats available for rent (six pontoon boats and five jet skis). Customers who rent pontoon boats are directed to proceed south from the marina to Maryland waters. Jet-ski customers must use the marked course in Little Assawoman Bay immediately north of the Route 54 bridge. The attendant commented that many boats come from Little Assawoman Bay and go under the Route 54 bridge every day heading to Maryland waters for fishing.

We counted 17 boats at Shark's Cove Marina (nine pontoon boats) and 13 empty slips. The marina attendant indicated there were still slips available in the marina. He noted that this vacancy may be due to the poor economy. There were 26 more boat slips at a nearby townhouse complex.

We visited Treasure Beach RV Resort. There are over 1,000 sites. There were no counts available, but an attendant reported that campers at most of the waterfront sites do have boats. We estimated there were 250 boats in this RV complex. We visited Magnolia Shores and Bulls Landing (residential developments up Dirickson Creek, near the Route 54 bridge). We observed a few boats docked at private homes. At our final stop, we observed two people crabbing at Sassafras Landing in the Assawoman Wildlife Refuge at 2:00 p.m.

In summary, we conclude, based on this one-day field observation, that recreational impacts on Little Assawoman Bay are minimal. The primary water-quality impacts in the bay are probably associated with residential development, in particular, the canal developments in South Bethany and Fenwick Island. There appear to be no major water-use conflicts among or between recreational users. There also do not appear to be any serious environmental impacts caused by recreational users.



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