**US Army Corps
of Engineers**®
Philadelphia District

DELAWARE RIVER MAIN CHANNEL DEEPENING PROJECT

RESPONSE TO ADDITIONAL QUESTIONS TO DNREC'S LETTER DATED DECEMBER 21, 2001 TO CORPS OF ENGINEERS

RESPONSES TO QUESTIONS

IN A LETTER DATED DECEMBER 21, 2001 FROM DNREC TO CORPS OF ENGINEERS

Question 1. What is the revised number of cubic yards of material to be dredged from Delaware waters?

Response. The revised initial quantity of dredged material to be dredged from Delaware waters is 17.7 million cubic yards.

Question 2. What is the number of cubic yards of material to be placed at each of the following sites: Reedy Point South, Killcohook, Kelly Island, Broadkill Beach, Port Mahon, Rehoboth-Dewey Beach?

Response. The approximate amount of dredged material to be placed in each site is as follows:

Reedy Point South	844,000 cubic yards
Killcohook	3,409,000 cubic yards
Kelly Island	2,500,000 cubic yards
Port Mahon	340,000 cubic yards
Either Broadkill Beach **or** Rehoboth-Dewey Beach	1,700,000 cubic yards

Question 3. What is the added cost of the Main Channel Deepening Project for placing dredged material on Rehoboth-Dewey Beach?

Response. The added cost of placing material at Dewey-Rehoboth Beach over the cost to place the same amount of material at Broadkill Beach is approximately $5.50/cubic yard or an additional cost of $9,350,000.

Question 4. What is Delaware's financial obligation for the Main Channel Deepening Project and this amount increase if dredged material is placed at Rehoboth and Dewey Beach?

Response. Delaware's financial commitment to the project local share is $7.5 million. The non-federal project share is $85.5 million of which $35.5 million is committed by Delaware, New Jersey and Pennsylvania. The balance, $50 million, is DRPA's commitment. The change in placement of sand onto Delaware beaches may increase the project cost. If so, additional funding source would have to be identified.

Question 5. If economic loading were to be utilized for the Main Channel Deepening Project, what would the specific locations be?

Response. Economic loading would reduce dredged material transportation costs in any portion of the project where sand would be dredged with a hopper dredge. This would likely occur in the bay portion of the project area. The use of economic loading would result in substantial cost savings for the project

Question 6. Please provide a final chart for "Environmental Windows in State of Delaware".

Response. Please refer to the attachment for the Environmental Windows.

Question 7. What is the added cost for the Main Channel Deepening resulting from the imposition of dredging windows and will this result in an increase to Delaware's share of the cost?

Response. The dredging windows may have an effect on the cost of constructing projects in the Delaware Bay. The following is a summary of projects and their associated issues with regard to windows.

- **Kelly Island.** In order to construct Kelly Island, complete relief for one season from the horseshoe crab and winter flounder windows is required. No relief is required from blue crab, sandbar shark or other windows. The increase in cost to observe these windows is prohibitive to constructing the project, since any interrupted construction activity has a high degree of risk associated with total failure of the project.

- **Port Mahon.** The horseshoe crab window can be observed if relief is given from the blue crab and winter flounder windows or vice versa. (i.e. blue crab and winter flounder can be observed with relief from the horseshoe crab window). No other windows impact Port Mahon construction.

- **Broadkill Beach.** The sandbar shark window can be mitigated by construction revisions as detailed in response to 6 above. The additional cost is considered to be project inclusive. The anticipated dredging time for Broadkill Beach is between 10-12 months so observation of the horseshoe crab, blue crab and winter flounder windows in any combination will increase the cost to construct Broadkill Beach. An additional dredge or multiple barges will be required. Quantification of the cost increase is impossible due to the various combinations of windows and construction methods.

- **Egg Island Point.** Relief from the horseshoe crab, blue crab, and winter flounder windows is required to construct the project. The increase in cost to observe these windows is prohibitive to constructing the project, since any interrupted construction activity has a high degree of risk associated with total failure of the project.

Question 8. When will the final "DREDGE" model results be submitted?

Response. A report titled *Near-Field Water Quality Modeling of Dredging Operations in the Delaware River*, which documents the results of the DREDGE model simulations conducted for the Delaware River Main Channel Deepening Project, was submitted to the Delaware Department of Natural Resources and Environmental Control on 19 December 2001.

Question 9. What specific measures will be put in place to address environmental concerns with the placement of dredged material at confined disposal sites, Kelly Island and beach replenishment sites? A summary chart would be helpful.

Response.

- **Confined Upland Disposal Facilities**

Effluent Discharge

The quality of effluent discharged from the Reedy Point South Confined Disposal Facility (CDF) would be monitored during dredged material disposal operations. Monitoring would follow similar procedures as those used to conduct the *Pedricktown Confined Disposal Facility Contaminant Loading and Water Quality Analysis* (October 2000) and *Killcohook Confined Disposal Facility Water Quality Analysis* (February 2001) studies. Reports documenting these efforts have been previously provided to the Delaware Department of Natural Resources and Environmental Control. In addition, subsequent to disposal operations, surface sediment samples will be collected from the CDF and analyzed for total contaminant concentrations. The data will be evaluated using U.S. Environmental Protection Agency ecological risk assessment methodology. Scopes of Work for both of these efforts were submitted as part of the Delaware River Main Channel Deepening Project permit application.

Groundwater Monitoring

The USACE in conjunction with the New Jersey Department of Environmental Protection (NJDEP) has developed a groundwater-monitoring program for federally owned confined upland disposal facilities (CDFs). The CDFs , which are to be continually used for the Main Channel Deepening project, are all located in New Jersey and now have monitoring wells. These monitoring wells along with the groundwater-monitoring program are designed to ensure that our confined disposal areas (CDFs) are not adversely impacting the drinking water aquifers.

This comprehensive groundwater-monitoring plan has been approved by the NJDEP and sampling is scheduled to begin in Spring 2002. The monitoring plan is intended to establish a baseline for all of the CDF's. After 2 years of monitoring all of the federally owned Main Channel CDF's, the plan calls for a final report on each of the CDF's, which will recommend a custom-monitoring plan tailored to each CDF. Once the site-specific CDF plans have been approved by the NJDEP, the site-specific CDF groundwater monitoring plans will then be implemented.

The USACE has also installed monitoring wells at the two sites in Delaware (Reedy Point North and Reedy Point South). A separate groundwater-monitoring plan (very similar to the NJDEP approved plan) has been sent to DNREC and we are awaiting their approval. Once DNREC approves the plan we intend on implementing groundwater monitoring at Reedy Point North and Reedy Point South.

Similarly, groundwater-monitoring program will be prepared and coordinated with NJDEP for the new CDFs (all located in State of New Jersey) to be acquired by the project sponsor, the Delaware River Port Authority.

- **Kelly Island**

Please refer to the attached table goals and objective table dated November 2000 for Kelly Island Wetland Restoration Project.

- **Beach Replenishment**

Monitoring for horseshoe crabs and shorebirds are planned at Port Mahon and Broadkill Beach. Restoration of *Sabellaria vulgaris* habitat is planned for Broadkill Beach and will be monitored. Copies of preconstruction studies for these species are attached and are on submitted CD ROM.

Question 10. If, during dike construction or disposal of dredged material at Kelly Island, it is determined that any sediment plume is adversely affecting shellfish beds, what remedial actions can be taken?

Response. The table referenced in question 9 states that the following remedial action would be taken.

- Alternatives will be developed to divert sediment transport away from oyster grounds.
- Construct diversions.
- If diversions are not successful, investigate restoration technology and methods.
- Restore oyster habitat.

Question 11. When will final plans and specifications for all of the Main Channel Deepening Project be completed?

Response. Final plans and specifications are required for a minimum of 10 separate contracts. Several sets of plans and specifications are near complete, with others to follow periodically over the next 4-6 years depending on project funding.

Question 12. What will be the extent of monitoring for disposal operations at Kelly Island, Broadkill Beach and Rehoboth-Dewey Beach?

Response. Monitoring at Kelly Island is described in question 9 above. Monitoring for horseshoe crabs, shorebirds and *Sabellaria* are planned for Broadkill Beach. No monitoring is planned at Rehoboth-Dewey Beach. Copies of preconstruction studies for horseshoe crabs, shorebirds, and Sabellaria are attached and are on the submitted CD ROM.

Questions 13. For the Main Channel Deepening Project, what procedures will be in place to alter or cease the dredging if the results of water quality monitoring indicate a violation of Delaware's Surface Water Quality Standards?

Response. If water quality violations occur at the dredging locations, the Corps contractor will be required to modify his dredging techniques. The Corps contract specifications will be performance based. If such violations occur, the contractor can use various operational techniques which include, but are not limited to, step cutting, minimizing cuts, concentric arc sweeping, spud carriage system, avoidance of anchor dragging, pipeline flushing, and pipe maintenance.

Question 14. The Corps application for Delaware permits does not contain the raw data used for calculating the cost-benefit figure. Would you please furnish this data for the record along with the rationale used for the figures?

Response. The benefit analysis applied the Corps of Engineers regulation ER 1105-2-100. The specific section used is, "NED Benefit Evaluation Procedures: Transportation, Deep Draft Navigation", pages E-37 though E-54 in the latest version of the regulation, dated 22 April 2000.

A copy is provided of the benefit-cost analysis summary table from the last approved report, Delaware River Main Channel Deepening Project, Limited Reevaluation Report, February 1998, Table 4, "Annualization Of Project Cost (Benefit-Cost Summary)", page 24. The benefit-cost ratio was 1.4, with average annual benefits of $40,143,000 and average annual costs of $28,780,000.

Question 15. How was the ten million dollar figure calculated as Delaware's share for the Main Channel Deepening Project?

Response. Delaware has agreed to contribute $7.5 million toward the non-federal cost share based upon discussions among parties to the Project and the State of Delaware. In return, the State of Delaware should receive an estimated $13 to $15 million in direct benefits (savings of non-Federal cost share for initial construction) for scheduled beach replenishment and tidal habitat restoration.

Question 16. The hearing record does not include water quality monitoring from CDF's located in New Jersey that discharge into Delaware's waters. What monitoring is planned at these CDF's?

Response. Effluent discharge and groundwater monitoring will be conducted.

Effluent Discharge. The Corps has an agreement with the New Jersey Department of Environmental Protection, which includes monitoring the quality of effluent discharged from Confined Disposal Facilities (CDFs) during dredged material disposal operations and groundwater monitoring at each CDF. Effluent monitoring will be conducted similar to what is planned for Reedy Point South and what has previously been employed at New Jersey CDFs. Refer to response to item 9 for previous studies conducted at New Jersey CDFs.

Groundwater Monitoring. Refer to response to item 9.

Question 17. How many chronic toxicity tests are planned?

Response. Based on discussions with Mr. Richard Greene of the Delaware Department of Natural Resources and Environmental Control, the chronic toxicity of effluent discharged from the Reedy Point South Confined Disposal Facility will be estimated via two (2) seven-day, static renewal, water column bioassays. Test procedures will follow: *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms* (EPA/600/4-91/003) July 1994. The inland silverside (*Menidia beryllina*) (Method 1006.0) and the mysid (*Mysidopsis bahia*) (Method 1007.0) will be used as indicator species. One test will be run with each species. The test design will include the required number of serial dilutions and controls, and replicates of each as indicated by the methods. Effluent concentrations shall include 100%, 50%, 25%, 12.5% and 6.25%. Test solutions will be renewed on a daily basis, with collection of new effluent samples on days one, three and five.

Question 18. The water quality monitoring plan for Reedy Point South CDF site states that monitoring at the weir will take place for 42 days. Shouldn't the monitoring continue until there is no longer a discharge from the CDF?

Response. Monitoring would be conducted for the entire period of discharge. The referenced monitoring plan is an actual Scope of Work that would be used to contract the required services. As such, it is necessary to define the exact amount of effort required so that the contractor can prepare a bid for conducting the study. Forty-two days (six weeks) was used as an estimate of a typical discharge period. If the discharge lasted longer than six weeks, then the contract would be modified to provide funds for the additional effort.

Question 19. Will all monitoring data be given to DNREC in digital format?

Response. Yes.

Question 20. Will bird activity at the CDF's be monitored for three years following the protocol developed by the Manoment Bird Observatory under the Special Area Management Plan for Pea Patch Island?

Response. Killcohook and Reedy Point are the likely candidate CDFs for monitoring. Corps would need to coordinate with both NJDEP and DNREC to finalize the scope of work and identify funding sources.

Question 21. What remediation plans will be put in place if CDF sediment does not meet DNREC Remediation Standards?

Response. Assuming that it pertains to effluent discharge, the CDFs are designed to handle the anticipated material without violating the suspended solids restrictions. Any violations of standard will require shut down of dredging operations until the standard can be met. This will require measures such as but not limited to, additional ponding, modified pumping speed and quantity, and or intermittent dredging.

Question 22. What method will be utilized to conduct a special study to measure suspended solids source strength in a fine grained reach and in a coarse grained reach within Delaware waters?

Response. Dr. Donald F. Hayes from the University of Utah has used a frame mounted on the dredge cutterhead. The frame has sampling ports set at known distances from the cutterhead, with tubing attached to a pump located on the deck of the dredge. He also uses turbidity sensors placed adjacent to the sampling ports to provide continuous recordings. His focus has been on the lateral dimension, but the vertical dimension could also be evaluated. A time-stamped video record of the monitoring event is also useful to explain any data anomalies identified during analysis. Monitoring should include characteristics of the dredge such as flow and production rate. Key properties of the sediment should also be measured such as grain size and density. Three days of sampling at a dredge site with similar conditions is sufficient to capture variability due to sampling. The turbidity/suspended solids data is then used to calculate the sediment source strength generated by the dredge.

Question 23. What specific modifications to the dredging operations to address water quality violations that have been developed since those described in "Techniques to Reduce the Sediment Resuspension Caused by Dredging" by G.L. Raymond?

Response. If water quality violations occur at the dredging locations, the Corps contractor will be required to modify his dredging techniques. The Corps contract specifications will be performance based. If such violations occur, the contractor can use various operational techniques which include, but are not limited to, step cutting, minimizing cuts, concentric arc sweeping, spud carriage system, avoidance of anchor dragging, pipeline flushing, and pipe maintenance.

Question 24. Will the results of water quality monitoring data be compared to both DRBC and DNREC water quality standards?

Response. Water quality monitoring data will be compared to New Jersey Department of Environmental Protection, Delaware Department of Natural Resources and Environmental Control and Delaware River Basin Commission water quality criteria.

Question 25. What protocol will be used to assess fish, shellfish, and other wildlife directly lost to dredging activity to include protocol for collecting, preserving and reporting loss of endangered species?

Response. The following aquatic resources will be monitored to assess direct effects of dredging/blasting.

<u>Shortnose Sturgeon.</u>

The protocol recommended by the NMFS in their Biological Opinion **(EXHIBIT 22)** will be followed during blasting operations. The entire Biological Opinion has been previously supplied to DNREC and this protocol is summarized below:

If any whole shortnose sturgeon (alive or dead) or sturgeon parts are taken incidental to the project, Carrie McDaniel (978) 281-9388 or Mary Colligan (978) 281-9116 must be contacted within 24 hours of the take. An incident report for shortnose sturgeon take (Appendix A) should also be completed by the observer and sent to Carrie McDaniel via FAX (978) 281-9394 within 24 hours of the take. Every incidental take (alive or dead) should be photographed and measured, if possible. The supervisory principal biologist will have had training in shortnose sturgeon biology, so if a sturgeon is injured, he/she should be able to recognize the severity of the shortnose sturgeon's injury. If the fish are badly injured, the ACOE should retain the individuals, if possible, until obtained by a NMFS-recommended facility.

A final report summarizing the results of the blasting and any takes of listed species must be submitted by the ACOE to Carrie McDaniel, NMFS Protected Resources Division, One Blackburn Drive, Gloucester, MA 01930 (978-281-9388; FAX 978-281-9394), within 30 working days of completion of the blasting project.

The ACOE must notify NMFS when the Delaware River blasting reaches 50% of the incidental take level for shortnose sturgeon (1 fish from injury or mortality).

NMFS anticipates that no more than 2 shortnose sturgeon will be incidentally taken from injury or mortality as a result of the proposed rock blasting portion of the Delaware River Deepening Project. NMFS anticipates that an unquantifiable amount of shortnose sturgeon will be incidentally taken from harass, trap, capture, or collect as a result of the sink gillnets set around the blast area. The reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize the potential for and impact of incidental take that might otherwise result from the proposed action. If, during the course of the action, the level of incidental take is exceeded, such incidental take represents new information requiring re-initiation of consultation and review of the reasonable and prudent measures provided. When the incidental take has been reached/exceeded, the ACOE must immediately provide an explanation of the causes of the taking and review with the NMFS the need for possible modification of the reasonable and prudent measures.

Impacts to other fish during blasting will be monitored in addition to impacts to shortnose sturgeon.

Sea Turtles.

Sea turtles are monitored for hopper dredging between Delaware River Mile 0 and 69 from 1 June to 30 November. Attached is a typical scope of work that would be part of a dredging project.

Blue Crab.

Populations will be monitored in areas where dredging is proposed during the winter window. Refer to **EXHIBIT 24** for the 2000/2001winter crab study.

Atlantic Sturgeon.

The Corps will also monitor for Atlantic sturgeon between 1 May and 1 October for hopper dredging between Bombay Hook, Delaware and the Commonwealth of Pennsylvania and State of Delaware boundary. The protocol would be the same as that described for sea turtles.

Other resources to determine indirect impacts that will be monitored include: horseshoe crabs, shorebirds, oysters, *Sabelleria.* Additional resources to be monitored at Kelly Island are discussed in the attached "Goals" table.

Question 26. Does the Corps of Engineers intend to abide by all of the protocols recommended in Section 7 Consultation on Endangered Species?

Response. Yes.

Question 27. Will the Corps of Engineers comply with a dredging window of December 1-March 31 in order to protect over wintering blue crabs in the main channel?

Response. The Corps of Engineers will comply with this window unless ongoing studies indicate and DNREC agrees that dredging within this window will not significantly impact overwintering blue crabs. Also refer to response to question 7.

Question 28. Is the Corps of Engineers willing to mitigate for the loss of Sabellaria, blue mussels, oysters, and epifaunal committees that exist of Delaware Bay beaches either by replacement of stone groins or by placement of cobble?

Response. If the ongoing studies conclude that the project will adversely impact the particular species, the Corps, in coordination with the Federal and State regulatory agencies will develop a plan that is acceptable considering engineering, environmental and cost parameters. The current plan is to compensate for loss of *Sabellaria* habitat at Broadkill Beach by placement of rock below mean low water at the locations of five existing groins along the beach.

Question 29. Is the Corps of Engineers willing to transport blasted rock to a suitable open water site to be utilized for artificial reef construction?

Response. The current plan requires rock to be disposed of at the Corps' Fort Mifflin CDF. There is substantial additional cost associated with the transport of rock to open water sites in the Delaware Bay. The Corps is willing to transport the rock to these locations assuming the additional incremental cost is borne by interested parties.

Question 30. The Atlantic Marine Fisheries Commission's Interstate Fisheries Management Plan for Horseshoe Crabs (ASMFC), 1998) recommends a seasonal restriction for beach nourishment of April 15 to August 30 to minimize adverse project- related impacts. The Corps of Engineers is proposing an April to June 30 restriction. Can Main Channel Deepening Project be accomplished with the April 15 to August 30 window and is the Corps of Engineers in agreement with this restriction?

Response. The restriction of 1 April to 30 June was in the Corps of Engineers' Supplemental EIS (1997) and was recommended by the U.S. Fish and Wildlife Service at that time. In subsequent coordination with DNREC, the Corps has adopted the 15 April to 30 August window for horseshoe crabs. The Corps intends to abide by this window unless ongoing studies indicate and DNREC and other appropriate agencies agree that work within the window will not significantly impact the horseshoe crabs. Kelly Island may not be able to be constructed unless work can be done within the window. Please see the discussion of the horseshoe crab window under question 6.

Question 31. When will the Varsar study on juvenile horseshoe crab abundance in the proposed sand placement areas be submitted to DNREC?

Response. Data collected by Versar on horseshoe crab adults and juvenile is attached.

Question 32. If Port Mahon is selected for sand placement, will the dredging window be the same as the one established for Kelly Island?

Response. It would be preferred to have the same dredging windows for these projects since they are adjacent to each other and could be constructed together which would be cost effective. However, as mentioned above in question 6, it is most critical that Kelly Island be constructed continuously to protect its integrity.

Question 33. Is the Corps of Engineers willing to conduct bimonthly beach egg density monitoring in May and June during sand placement on beaches and a late fall sampling using the Weber protocol in order to quantify beach recovery and use?

Response. The Philadelphia District has agreed to monitor horseshoe crab egg density for three years after construction during May and June to determine if spawning was occurring. Dr. Richard Weber also recommends that a sample be taken in late September when the greatest number of hatchlings would be present to determine hatching success. We are willing to do this as well.

Question 34. As the local sponsor for the Main Channel Deepening Project and the party responsible for obtaining disposal sites, is the Delaware River Port authority willing to sign on as a co-applicant for Delaware permits?

Response. The permit applicant is the U.S. Army Corps of Engineers. Thus, the Corps is the only appropriate signatory.

Question 35. Is the Corps of Engineers willing to conduct sediment grains size analysis and beach slope surveys as part of the monitoring for horseshoe crab impacts resulting from sand placement?

Response. The Corps of Engineers has agreed to measure these variables as part of monitoring for horseshoe crabs at Kelly Island and will also do so at other selected sand placement sites in Delaware Bay.

Question 36. Is the Corps of Engineers willing to monitor shorebird use in order to quantify changes resulting from sand placement to include an analysis of at least a part of the data in the context of the bay – wide survey to evaluate the relative importance of these sites to the Delaware Bay shorebird use?

Response. The Corps is willing to monitor shorebird use at the Kelly Island restoration site and other selected sand placement areas in Delaware Bay for three years after construction.

Question 37. Is the Corps of Engineers willing to monitor the density of young hatchlings that may potentially be present in the intertidal zone near the sand placement sites using a standard protocol developed and approved by DNREC for this activity?

Response. The Corps of Engineers is willing to work with DNREC and other agencies to develop and implement a protocol for monitoring the density of horseshoe crab hatchlings at selected sand placement areas in Delaware Bay.

ATTACHMENTS

US Army Corps
of Engineers®
Philadelphia District

DELAWARE RIVER MAIN CHANNEL DEEPENING PROJECT

ENVIRONMENTAL WINDOWS IN DELAWARE

DELAWARE RIVER MAIN CHANNEL DEEPENING PROJECT ENVIRONMENTAL WINDOWS IN DELAWARE

RESOURCE	**ACTIVITY**	**EXISTING ENVIRONMENTAL WINDOWS**	**PROPOSED CHANGES TO WINDOWS***
Fish	Rock Blasting Overboard Disposal in All Areas	15 March-30 Nov. (Delaware Memorial Bridge to Betsy Ross Bridge)	None
Anadromous Fish	Bucker Dredging	16 March to 31 May above River Mile 62 (Pea Patch Island)	None
Shortnose Sturgeon	Hydraulic Dredging in Non-Federal Channels	15 April-21 June (Delaware Memorial Bridge to Kinkora Range)	None
Shortnose Sturgeon	Bucket Dredging in All Areas	15 March-31 May (Delaware Memorial Bridge to Kinkora Range)	None
Atlantic Sturgeon	Hopper Dredging in All Areas	Monitors required from 1 May and 1 October between Bombay Hook, DE and the PA/DE boundary	None
Sea Turtles	Hopper Dredging in All Areas	1 June-30 November (Delaware Bay to Delaware Memorial Bridge; Sea Turtle Monitors Required)	None
Pea Patch Island Wading Bird Colony	Dredging within 2600 ft of Colony	1 April-31 August	None
Shorebirds and Horseshoe Crabs	Construction of Kelly Island Wetland Restoration andBeach Nourishment	15 April to 31 August (Area of concern is on the beach)	See discussion below.
Sandbar Shark	Beach Nourishment at Broadkill Beach	1 May to 15 Sept. (Area of concern is in the water just offshore)	See discussion below.
Winter Flounder	Dredging and Sand Placement below River Mile 35.	1 January to 31 May	See discussion below.
Over-wintering female blue crabs	Channel Dredging in Bay below RM 32.	1 December to 31 March	See discussion below.

****ANY CHANGES TO THE EXISTING ESTABLISHED ENVIRONMENTAL WINDOWS WOULD FOLLOW THE FOLLOWING PROTOCOL:***

CORPS OF ENGINEERS PROCEDURES FOR REQUESTING CHANGES IN CLOSED ENVIRONMENTAL WINDOWS

- **PLANNED CHANGES**

  These changes would be requested where we believe that data indicates that work could be performed within the environmental window without significantly impacting species of concern. For the Delaware River Main Channel Deepening Project data is being gathered by the Corps for species such as the horseshoe crab, shorebirds, and blue crab that may indicate that work can be done within the environmental windows because of small numbers of animals within the work areas. This data will be coordinated with appropriate State and Federal agency personnel, including species experts, and submitted to the appropriate State offices (such as DNREC Coastal Zone or Wetlands) and/or Federal resource agency office (such as USFWS or NMFS) with the request for working within the windows. A meeting may be useful to discuss the issues.

  Another possibility is to modify construction techniques to eliminate potential impacts to the species in question. This is being considered for the winter flounder and sandbar shark where coordination is proceeding with the National Marine Fisheries Service as part of an Essential Fish Habitat Evaluation.

- **UNPLANNED CHANGES**

  This would occur when an unplanned event occurs such as an adverse weather condition that has delayed project construction. This would usually involve working in the window for a relatively short period of time. Coordination would be done with the appropriate State/Federal agency to determine if this work could be done without significantly impacting the species in question.

Shorebirds and Horseshoe Crabs

A monitoring/management plan was developed for the Kelly Island wetland restoration project and has been closely coordinated with DNREC and Federal resource agencies, including personnel from the Bombay Hook National Wildlife Refuge. Kelly Island has been eroding for many years. See the attached diagram that shows the 2001 shoreline superimposed on a 1926 photo. In 1926 the percent of sandy beach in the reach of shoreline that will be restored by the wetland restoration was 100%; in 2001 the amount of potential horseshoe crab spawning habitat in 49.9%. The project would restore this to 100%.

One of the goals of the monitoring/management plan for Kelly Island that was developed by this interagency group was to create spawning habitat for horseshoe crabs. The horseshoe crab egg density and habitat availability study was done at the three areas in Delaware Bay in Delaware where we propose to place dredged material: Kelly Island, Port Mahon, and Broadkill Beach. One of the goals of this study was to establish pre-construction conditions at these areas to be compared to post-construction horseshoe crab use. Another reason that this information was needed was to see if work could be done within the environmental window (15 April to 31 August) established by the Atlantic States Marine Fisheries Commission's *Interstate Fishery Management Plan for Horseshoe Crab* (1998).

This is especially critical for Kelly Island wetland restoration that will take over a year to construct. There is a concern that if construction is not completed in a continuous manner, the structure may be compromised. We plan to gather additional data on spawning horseshoe crabs at Kelly Island in 2002, as well as at Broadkill Beach and Port Mahon. We have also gathered data on juvenile horseshoe crabs for these three areas, as well as Kitts Hummock (a known productive spawning area recommended by DNREC as a control), as well as data for spawning adults at Kelly Island and Port Mahon. After we have completed these studies, we are planning to meet with DNREC , the National Marine Fisheries Service, the U.S. Fish and Wildlife Service and other appropriate experts to discuss population levels and construction techniques that may be able to avoid or minimize impacts to horseshoe crabs. It is noted that only 49.9 % of Kelly Island and 26.9 % of Port Mahon was found to be suitable spawning habitat in 2001. Restoration efforts at Kelly Island and Port Mahon are expected to greatly enhance the spawning habitat. Much of the shoreline at Kelly Island is under lain with peat and unsuitable for spawning. The shoreline at Port Mahon is lined with rock rip rap that results in the mortality of many spawning horseshoe crabs each year.

Sandbar Shark

The habitat along the lower Delaware Bay coast in Delaware has been designated as "Habitat Areas of Particular Concern" by the NMFS. Pratt (1999) believes that there will be a great potential to impact shark pups and their food source of benthic organisms in the nursery areas along the Delaware Bay Coast, especially offshore from Broadkill Beach to Slaughter Beach, if sand is deposited near the beach (in areas 1 – 4 m deep) in the nursery season. Potential impacts may include but not be limited to: changing the habitat characteristics, depth, profile, odor, turbidity and fauna of the area. Loss of forage would also occur. Prey species, principally crabs and fish of many species, may be disrupted directly by the presence of physical activity in the area and indirectly by the covering of vulnerable food web organisms with sand. A "closed" window from 1 May to 15 September was recommended by the National Marine Fisheries Service (Gorski, 2000) to prevent potential impacts to newborn and juvenile sharks such as suffocation. After this time period, the young sharks have reached a larger size where they would be more able to avoid the sand placement operations.

On 7 November 2000 representatives from the Corps and the NMFS held a teleconference to explore methods to place sand on Broadkill Beach during the Spring/Summer without significantly impacting the sandbar sharks puping (females giving birth to live-born young) and the nursery area that is located offshore in shallow waters. It was agreed that sand placement can be performed during the period from 1 May to 15 September using the following conservation measures:

a. A sand dike, 200 to 300 feet in length, will be constructed above mean high water (MHW) to contain dredged material that is pumped landward of it. The dike will be constructed using existing sand on the beach. The dike will be long enough that most dredged material will drop out on the beach and not return to the bay. As material is deposited the dike may be repositioned seaward to contain the required filling above MHW for that section of Beach. The slurry will still be controlled by the dike along the shoreline. No dredged material will be hydraulically placed below MHW during the restricted period. The dike will be extended down the beach as the area behind the dike is filled and the dredged pipe is lengthened. The dredged material that has been deposited will be built into dunes. It is expected that little of this material will be re-deposited by wave action during the spring/summer window period since weather is generally mild, except for possible hurricanes. After September 15, some dredged material will be graded into the bay to widen the beach.
b. The dredged pipe will be placed on pontoons for a minimum of 1000 feet, beginning at approximately elevation –4.7 NGVD, extending offshore to avoid disrupting along shore traveling by the young sandbar sharks. This distance will be determined by the National Marine Fisheries Service. The remainder of the pipeline extending to the beach, and back to the dredge, can rest on the bottom.

References:

Gorski, Stanley W., 2000, Letter to John T. Brady dated February 10, 2000, National Marine Fisheries Service, Highlands, NJ.

Pratt, Harold "Wes", 1999, Letter to John T. Brady dated October 4, 1999, National Marine Fisheries Service, Narragansett, RI.

Winter Flounder

The winter flounder in Delaware Bay are part of the Mid-Atlantic population that migrate inshore in the fall and early winter and spawn in late winter and early spring. In Delaware Bay, spawning takes place January, February and March, with early life stages being present in April and May (Riportella, 2001). Trawl surveys by the Delaware Department of Natural Resources and Environmental Control indicate that they are not abundant and that they occur in the lower portion of Delaware Bay where there are higher salinity levels (Michels, 2000). Generally the concern for winter flounder extends from the mouth of Delaware Bay to River Mile 35.

Deepening the Navigation Channel has the potential to impact winter flounder if they were present; however, it is unlikely that the navigation channel has any significant use by this species.

The Deepening Project has the potential to impact eggs during the dredging of the channel and during the placement of the dredged material. It is likely that dredging will have a minimal impact on eggs of this species for the following reasons. First, most eggs have been found in shallow water, less than 5 meters. The navigation channel is presently 40 feet (12.2 meters) or greater and will be deepened to 45 feet (13.7 meters). Although eggs have been found in the 45 feet deep navigation channel of New York Harbor, the adjacent, shallow areas had greater densities, indicating that the more shallow water areas are preferred spawning habitat (Gallo, 2001). Another reason that winter flounder are likely to prefer areas adjacent to the navigation channel is that the deep draft vessels currently using the channel are creating more turbid conditions in the channel with their prop-wash that is likely to adversely impact spawning.

Since the larvae are non-dispersive, they are believed to occur in the same areas as the eggs, i.e. in shallow water. Because of the reasons listed above for eggs, it is unlikely that the navigation channel would provide preferred habitat for larvae.

Any juveniles or adults that use the channel could be adversely impacted by dredging, either by entrainment or increased turbidity. However, because of the channel's use by deep draft vessels and the resulting turbidity and prop wash, it is unlikely that the navigation channel has significant use from these life stages of winter flounder.

The placement of dredged material along the shallow shorelines of New Jersey and Delaware at the wetland restorations at Egg Island Point and Kelly Island and the beach restoration at Broadkill Beach and Port Mahon in Delaware Bay and Dewey-Rehoboth beaches along the Delaware Atlantic coast are more likely to have adverse impacts on spawning adults and early life stages (larvae and juveniles) than channel dredging. However, the impacts are not expected to be significant for the following reasons. First, as stated above, data from New Jersey and Delaware indicate that winter flounder populations currently using Delaware Bay are smaller than those further north in the range and become less abundant moving from northern New Jersey to southern New Jersey. In addition, the wetland restorations at Egg Island Point and Kelly Island will create tidal guts in the wetlands with abundant invertebrate fauna that will be beneficial to early life stages of winter flounder that will compensate for any temporary, minimal impacts that would occur from the construction of the two wetland restorations (Goodger, 2001). It is also noted that the construction of these structures is a one-time event except for occasional maintenance that can be done outside the winter flounder window.

Winter Flounder References:

Gallo, Jenine, Email to John Brady, New York District, Corps of Engineers, April 10, 2001.

Goodger, Personal Communication, National Marine Fisheries Service, Oxford, MD, April 20, 2001.

Michels, Stewart. Personal Communication, DNREC. December 13, 2000.

Riportella, Anita, 2001. Personal Communication, National Marine Fisheries Service, Highlands, New Jersey.

Over-Wintering Female Blue Crabs

A study titled *Delaware River Main Channel Deepening Project Delaware Bay Winter Crab Survey – 2000/2001* was completed in October 2001 and submitted to DNREC. This report covers the first year of pre-construction monitoring. Pre-construction monitoring will continue until construction begins and subsequent reports will be provided when available.

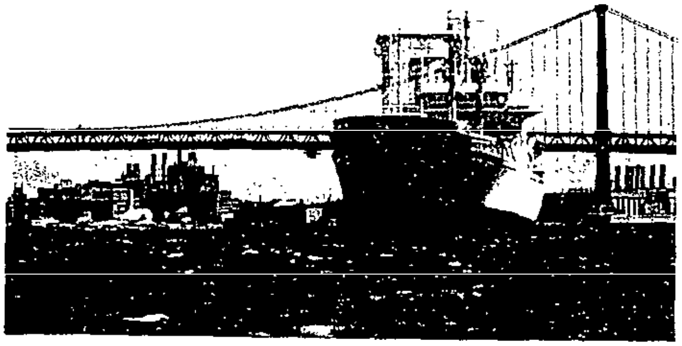
The study indicates that about 0.1 percent (about 70,000 crabs) of the crabs hibernating in lower Delaware Bay would be impacted. Although this loss should not impact the Delaware Bay blue crab population, the Philadelphia District will continue to coordinate with DNREC to explore methods to minimize this impact.

US Army Corps
of Engineers
Philadelphia District

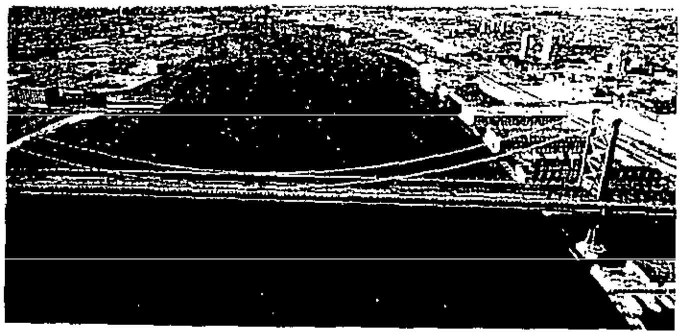
Philadelphia District
North Atlantic Division

Delaware River Main Channel Deepening Project

LIMITED REEVALUATION REPORT



Vessel Entering Philadelphia Harbor



Benjamin Franklin Bridge (PA/NJ)

Packer Avenue Terminal (PA)

Beckett Street Terminal (NJ)

February 1998

TABLE 4
ANNUALIZATION OF PROJECT COST
(BENEFIT-COST SUMMARY)

October 1996 Price Level- Discount Rate 7-3/8%

Construction Year	Description	Cost*	Present Worth Factor	Present Worth Cost
1	Project Cost	$71,262,000	1.282806	$91,415,350
2	Project Cost	$69,894,000	1.194697	$83,502,185
3	Project Cost	$87,630,000	1.112640	$97,500,665
4	Project Cost	$15,886,000	1.036219	$16,461,376
1	Real Estate	$18,598,000	1.000000	$18,598,000
4	Navigation Aids	$946,000	1.036219	$980,263
4	Associated Costs	$22,079,000	1.000000	$22,079,000
1	PED Costs	$10,000,000	1.329268	$13,292,685
TOTAL ECONOMIC COST				$343,829,524
TOTAL PRESENT WORTH - WITHOUT INTEREST DURING CONSTRUCTION (IDC) CRF (50 Years, 7.375%) -0.075913				$296,295,000
AVERAGE ANNUAL COSTS(ECONOMIC COST & IDC)				$26,101,000
AVERAGE ANNUAL INCREMENTAL OPERATION & MAINTENANCE COSTS				$2,679,000
TOTAL AVERAGE ANNUAL COSTS				$28,780,000
TOTAL AVERAGE ANNUAL BENEFITS				$40,143,000
NET BENEFITS				$11,363,000
BENEFIT TO COST RATIO				1.4

* This cost represents the unesculated project cost.

KELLY ISLAND WETLAND RESTORATION GOALS TABLE

Delaware River Main Channel Deepening Project
Kelly Island - Wetland Restoration/Protection: Goals Table

1-Nov-00

Goal	Objectives	Performance Standard	Measurement Method	Remedial Action
Jse dredged material to create and stablish 60-acre tidal wetland that rovides habitat for native species horseshoe crab, shorebirds, fish, *partina*, waterfowl) and prevents ontinued erosion of Kelly Island vithout significant adverse impacts o contiguous habitats.	Prevent deleterious effects to adjacent shellfish (oyster) populations and habitat.	No significant increase in anaerobic (smothered) conditions of shellfish beds when compared to pre-project conditions in the same locations.	Using sediment profiling camera with plan view attached, develop reference photographs of existing oysters so that reasonable color comparisons can be made in the future. Reference photos of anaerobic sediments will be obtained from existing imagery files. Photos will be taken quarterly during preconstruction and construction and for three years following construction. Transects will be set up between Kelly Island and the nearest oyster areas as well as control transects both north and south of Kelly Island.	1. Validate cause of anaerobic conditions to determine if project related. 2. Investigate restoration technology and methods. 3. Restore oyster habitat.
		No transport of placed sand from project onto nearby oyster beds or leases.	Sediment grab sampling of bay bottom between project and oyster beds (Drum Bed, Silver Bed, and Pleasanton's Rock) once during preconstruction, and quarterly for one year after construction when the need for future sampling will be reevaluated. In addition, grab samples will be taken between the project and the nearest oyster beds after major storms, which is defined as either (1) a tide based storm where post-storm surveys shall be obtained when water levels at Lewes and/or Port Mahon equal or exceed +7.5 ft above MLLW during a storm event, regardless of whether there are erosion impacts detected/observed at the Kelly Island berm; or (2) Observation-based, where post storm surveys shall be obtained if there is apparent scarping or shoreline retreat of the Kelly Island berm, even if tide gage measurements at Lewes and Port Mahon fail to equal or exceed +7.5 ft MLLW. Samples taken after construction will be compared to samples taken prior to project construction. This assumes that the sand from the project will be (Continued on next page)	1. Alternatives will be developed to divert sediment transport away from oyster grounds. 2. Construct diversions. 3. If diversions are not successful, investigate restoration technology and methods. 4. Restore oyster habitat.

Goal	Objectives	Performance Standard	Measurement Method	Remedial Action
			distinctly different from the pre-project bay bottom and will therefore be traceable. Within one year before construction, side scan sonar or a similar imaging technology will be used to characterize the bay bottom between Kelly Island and the nearest oyster areas.This will be repeated one year after construction..Transects will be set up between Kelly Island and the nearest oyster areas as well as control transects both north and south of Kelly Island.	
		No significant increase in suspended solids from fine grained material contained by the berm. A significant increase would be more than 25% above the yearly preconstruction mean.	Install a turbidity measuring instrument. Data will be gathered for one year prior to the construction of Kelly Island, during construction, and for three years after construction. In addition quarterly inspections will be done to inspect the berm for breaches.	Repair berm. Restore oyster habitat.
	Silt retained for periods between maintenance of the offshore sand dike and other features.	Shoreline retreat rate of less than 14 ft per year on average over 10-year period after construction. Additionally, equilibration of dike slope in first year should not result in shoreline recession of greater than 30 ft. (WES design criteria).	Annual cross-sectional surveys of offshore dike from landward edge of crest of dike to offshore toe of slope. Annual aerial photographs at 1:2400 scale.	Replenish cross-section of dike with sand if deemed necessary by the Corps and DNREC. Evaluate reasons for accelerated erosion. Mitigate with appropriate volume of sand to restore berm to expected condition.
	Contain silty dredged material.	Sufficient capacity in site to contain 200,000 cubic yards of fine sediments mixed with an additional 500,000 cubic yards of sandy sediments.	Observation of placement operation to be sure that placement of sand over silts reasonably mixes in the site. Water quality standards in the discharge from the site should not exceed those specified prior to dredging. During disposal of dredged material into the wetland restoration area, water quality will be monitored at the discharge pipes with an automatic sampler. Emphasis will be on monitoring total suspended solids.	If water quality standards are not met, dredging operation will be modified to bring discharges within limits by methods such as increasing the ponding period, or decreasing the discharge rate.

Delaware River Main Channel Deepening Project

Kelly Island - Wetland Restoration/Protection: Goals Table

1-Nov-00

Goal	Objectives	Performance Standard	Measurement Method	Remedial Action
	Average annual sediment transport rate away from structure should not exceed 35,000 cubic yards.	Annual topographic and bathymetric surveys of offshore sand dike show change in dike volume not exceeding 35,000 cubic yards per year. (Some sediment will move on and offshore but can be accounted for in the volume calculations. Interest here is sand lost from the project to the north or south.)	Annual cross-sectional surveys of offshore dike from landward edge of crest of dike to offshore toe of slope. Annual aerial photographs at 1:2400 scale.	Assess cause and determine appropriate action .
	Created marshes similar to native low marshes on 40 acres (including hummocks).	Similar to adjacent reference marsh located on northern third of Bombay Hook tidal marsh.	1 year after tidal exchange established, survey area to assess natural plant recruitment using random or systematic 1-m plot methods used by the National Wildlife Refuge to be sure desired plants are present.	Assess cause and determine appropriate action.
			3 years after tidal exchange established, within +/- 3% species composition similarity with reference marsh or a desirable species composition as determined by the Corps, DNREC, and Federal Resource Agencies. In the creation of the vegetated low marsh, flexibility will be used when evaluating if the marsh is a success. Although the standard of having the vegetation within +/- 3% of the reference marsh will be used as a guideline, the Corps, DNREC and the Federal resource agencies will determine if the marsh is a "success" after vegetation has become established.	Consider modification of topography, eradication of undesirable species, planting of desired species, modification of water flow characteristics, and protection against geese and other animals eating the plants.
	Establish 50 ft width of beach grass on crest of berm/dike.	75% survival after 1 year from planting.	Field surveys for survival of planted stems yearly for three years.	More plantings of beach grass.

Delaware River Main Channel Deepening Project
Kelly Island - Wetland Restoration/Protection: Goals Table

1-Nov-00

Goal	Objectives	Performance Standard	Measurement Method	Remedial Action
	Optimize habitat for use by summer and winter flounder juveniles. Although the objective of maximizing summer and winter flounder habitat will focus on these species, an attempt will be made to create a diverse aquatic community that is similar to that which exists in the adjacent reference tidal marsh waterways.	Establish at least 1000 linear feet of tidal channel at least 0.1 m deep at mean low water (NMFS, 1999) within 1 year after tidal exchange is established. The width of the channel will be determined to maximize tidal exchange without causing erosion to the sides of the channels.	Yearly air photos. Seining in new and reference channels of created marsh and adjacent tidal marsh waterways in late spring one year after tidal flow is established to determine if species are present.	Assess cause and determine appropriate action such as modification of topography and modification of water flow characteristics.
	Maximize habitat for horseshoe crabs.	At mean high water line: 1. Depth of sand is at least 16 inches. 2. Sand has 2 to 6 % moisture at 3.7 in. below the surface. 3. Beach slope is 5 to 9 %. 4. Grain size is between 0.5 and 1.0 mm at 3.7 inches below the surface.	Measure variables as described in Brady and Schrading (1996) every 500 feet along the berm face, biweekly between 1 May and 1 July, for three years after construction. Measure density of horseshoe crabs eggs at same locations following protocol that is being developed by the Atlantic States Marine Fisheries Commission.	1. Adding sand to berm. 2. Grade berm.
	Insignificant horseshoe crab mortality due to design of project. For example, in or around structures, or in the marsh (if they were to migrate over the sand dike).	Less than 10 % of crabs trapped in structures or on landward side of berm.	Yearly visual observation and counts of crabs during spawning season. Comparisons will be made between the project and other natural areas where mortality occurs.	Sand fence at edge of vegetated top of berm.

Delaware River Main Channel Deepening Project
Kelly Island - Wetland Restoration/Protection: Goals Table

1-Nov-00

Goal	Objectives	Performance Standard	Measurement Method	Remedial Action
	On beachface, maximize feeding habitat for sanderlings, red knots, turnstones.	Since the main food for these species in Delaware Bay is horseshoe crab eggs, if horseshoe crab habitat is maximized, feeding habitat for these species will be as well.		
	In marsh, maximize habitat on a minimum of 20 acres for migratory shorebirds such as dowitchers, dunlin, semiplamated sandpiper, etc.	Less than 25% vegetative cover (Manomet, 1999) with 75% in a combination of mud flats and shallow water less than 12 cm at mean low water (Harrington, Undated).	Yearly air photos. Observations and counts of species using area during spring and fall migrations (could be incorporated into the aerial census being done by NJ and DE).	Assess cause of failure and determine appropriate action such as modification of topography and modification of water flow characteristics.
	Limit invasion of *Phragmites* Create marshes similar to native low marshes (including hummocks).	Less than 1% populated by *Phragmites* in monotypic stands in the marsh, as well as the berm and back dike.	Yearly air photos. Ground surveys.	Control of *Phragmites* using methods such as spot treatment of herbicides or water level manipulation.

PRECONSTRUCTION HORSESHOE CRAB EGG DENSITY MONITORING AND HABITAT AVAILABILITY AT KELLY ISLAND, PORT MAHON, AND BROADKILL BEACH STUDY AREAS, DELAWARE

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31 December, 2001

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PA 19107-3390

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PRECONSTRUCTION HORSESHOE CRAB EGG DENSITY MONITORING AND HABITAT AVAILABILITY AT KELLY ISLAND, PORT MAHON, AND BROADKILL BEACH STUDY AREAS, DELAWARE

Richard G. Weber

Background

Several species of migratory shorebirds and resident laughing gulls feed extensively on eggs of the horseshoe crab, *Limulus polyphemus* L., during its spring spawning season (Botton 1984, Burger and Gochfeld 1991, Castro and Myers 1993). For some shorebird species migrating to their arctic nesting grounds, the stopover on Delaware Bay beaches to feed on *Limulus* eggs may represent the most critical part of their annual reproductive cycle (Castro and Myers 1993). Migrating shorebirds have been shown to make body weight gains of 40%, or more, during their two to three-week stopover on Delaware Bay beaches in May (Castro, et al. 1989).

In Delaware Bay, most *Limulus* spawning occurs from April through July, with May and June being the peak months of activity (Shuster and Botton 1985). Female *Limulus* spawn near the high tide line beneath the beach surface in "nests", where they produce one or more clusters of adhering eggs. Clusters are deposited below the feeding zone of shorebirds. However, many of these clusters become dissociated before the eggs hatch, and their constituent eggs are dispersed through beach sediments, toward the surface. A simple census, for egg clusters only, can underestimate actual egg numbers present on a beach (Weber 1998, 1999a, 2000). Several studies have sampled beaches to determine the populations of horseshoe crab eggs present in beach sediments. Researchers examining *Limulus* spawning behavior have taken a variety of approaches, however no standardized sampling method for determining densities of *Limulus* eggs dispersed in beach sediments has emerged from the literature. Such a method would facilitate a variety of comparisons that would be especially useful in making coastal and estuarine management decisions. Examples include: quantification of dispersed-egg population densities on beaches most heavily used by migrating shorebirds, comparisons of dispersed-egg populations in heavily used beaches with egg populations of less-used beaches, comparison of annual variations in spawning activity on a particular beach, and investigation of the effects of beach erosion or beach replenishment on *Limulus* spawning.

The Army Corps of Engineers is proposing to use dredged material from deepening the Delaware River Federal Navigation Channel for shoreline restoration projects at Kelly Island, Port Mahon, and Broadkill Beach, areas on the Delaware Bay known to attract shorebirds and spawning horseshoe crabs. These projects are expected to increase the amount and quality of horseshoe crab spawning habitat, significantly improving the habitat quality for both horseshoe crabs and shorebirds. In order to determine whether the completed shoreline restoration has benefited these species at the site, it is necessary to collect and analyze quantitative and qualitative baseline data on horseshoe crab egg density prior to construction.

Currently an environmental window exists that prevents construction (ie. sand placement) to take place from 15 April to 31 August to prevent impacts to spawning horseshoe crabs. This window follows the recommendations of the Atlantic States Marine Fisheries Commission's *Interstate Fishery Management Plan for Horseshoe Crab* (1998). These projects will be extremely difficult to build if no construction is done during this period. It may not be possible to complete the Kelly Island wetland restoration. The Delaware Department of Natural Resources and Environmental Control has stipulated that unless the Corps of Engineers can provide site specific information to indicate that 1) the site is not being used as a horseshoe crab nursery area or 2) that horseshoe crab spawning and egg incubation has ceased for the year, then the above window would be applied. Site specific information will be needed for confirmation of these conditions if sand placement is requested within the general 15 April to 31 August closure window. During 2001, this study will estimate the amount of potential horseshoe crab spawning habitat that exists at each site, will sample horseshoe crab egg densities at these sites, and compare those egg densities to egg densities on other horseshoe crab spawning areas examined on the Delaware Bay coast in Delaware during the same period.

Objectives Of This Study

This study was conducted on Kelly Island, Port Mahon (both in Kent County), and Broadkill (Sussex County) beaches, in Delaware during the summer of 2001. The study was designed to gather information about the seasonal distribution and relative abundance of horseshoe crab (*Limulus polyphemus* L.) eggs in these beaches, as they currently exist. The study also evaluated shorelines of these beaches so the amounts and locations of spawning habitats currently available on each could be estimated.

This report presents information about horseshoe crab egg densities gained during studies conducted on Kelly Island, Port Mahon, and Broadkill beaches (all in Kent County) during the summer of 2001. In it, I summarize my findings, discuss them in relation to the literature of horseshoe crab spawning, compare them to data collected in a parallel 2001 study on three other Delaware beaches (North Bowers, Kitts Hummock, and Pickering, all in Kent County), and further compare them to data collected during studies conducted on several other Delaware beaches during recent summers.

Materials And Methods

Descriptions of the study beaches **Kelly Island** is not actually an island, but rather a marshy peninsula lying between the Mahon River and Delaware Bay. The southern part of Kelly Island, near the mouth of the Mahon River, is the area where a restoration project is being considered. **Figure 1, Appendix A** is an aerial photograph of the study area, taken in 1997. This is the latest georeferenced photograph of this area currently available from the Delaware Department of Natural Resources. The shoreline runs more-or-less true north. At low tide, most of the shoreline consists of irregular, vertical peat "cliffs", ranging in height from ca. 0.5–1.3 meters above low water. The high ground consists of compacted mud and peat. There are few locations where the sandy areas of upper beach grade smoothly down to the low water line. The upper edge of the beach is separated from the background marsh by a variable wrack line, consisting mostly of coarse vegetable detritus, deposited during periods of storm flooding. Bayward from this storm wrack line, and running irregularly along beside it, is a discontinuous band of wave-deposited sand of varying depth, covering the mud and peat substrate. Depth of this band ranges from approximately 40 cm at the upper edge to 2 cm at the lower edge. The band ranges in width from 2.1 m (7') to 8.5 m (28'), and in all but a few narrow places, is discontinuous with the tide flats, being separated from the low water line by variable expanses of mud and peat substrate which are well above the low water line All egg clusters and eggs that I found on this beach were in this band of sand.

The two study transects sampled on Kelly Island during this study were "North", and "South", whose upper (high beach) ends were located at N39°12.679', W075°23.913' and N39°12.431', W075°23.849', respectively. Locations of these points are shown on **Figure 1, Appendix A.** Approximate distance between the two transects was 418 m (1,373'). These transects were selected, after a preseason site assessment, as being representative of the other sandy sections examined along that shoreline. Owing to an error in communication, both transects were located beyond the northern boundary of the proposed restoration project. This was not discovered until after samples had all been collected and processed. Location of the northern boundary of the restoration project is shown on **Figure 1, Appendix A.**

Port Mahon beach has a northeasterly-oriented Delaware Bay shoreline. **Figure 2, Appendix A** is an aerial photograph of the study area, taken in 1997. This is the latest georeferenced photograph of this area currently available from the Delaware Department of Natural Resources. A sand road closely parallels the shoreline. The southern midsection of the beach has several sections of vertical metal breakwater, which persist from early attempts to protect the roadway. Breakwater sections parallel the shoreline 1–2 m out past the low tide line. The road is separated from the water by a variable band of riprap which consists principally of boulders in the 30 – 120 cm (1' – 4') size range. The lower edge of the riprap runs variously up and down through the intertidal area. In some places the lower edge of the riprap reaches out nearly to the low tide line. In other cases the lower edge rises somewhat above the middle part of the intertidal area. At lunar tides, water rises completely over some sections of riprap, and wave action erodes the roadway. As a result, the road is subject to continual grading and repair, with additional sand being added several times each year. Sand from this erosion and subsequent replenishment migrates downslope through the riprap, to create the sections of sandy beach upon which the horseshoe crabs spawn.

On the bay side of the riprap, the beach contains varying amounts of smaller (≤ brick size) miscellaneous chunks of macadam, masonry rubble, etc., applied long ago in attempts to stabilize and maintain the road. This trash material, together with random layers of shell, is variably covered with sand. The color and size uniformity of the sand particles along the riprapped beach areas suggest that most sand present is the result of erosion from the material used to repair the road. Much of what appears to be sandy beach is actually shallow sand underlain by clay hardpan, dense layers of shell, or miscellaneous trash material, and is generally unsuitable for spawning. Female horseshoe crabs seldom spawn in situations where the sand is not at least deep enough to nearly cover their bodies, approximately 10 cm (4").

The two study transects sampled on Port Mahon during this study were "North", and "South", whose upper (high beach) ends were located at N39°11.114', W075°24.071' and N39°10.794', W075°24.297', respectively. Locations of these points are shown on **Figure 2, Appendix A.** Approximate distance between the two transects was 671 m (2,203'). These transects were used for this study because they have been sampled in similar studies each year since 1998. They were selected in 1998 because they had the deepest, most uniform layers of sandy sediment along the Port Mahon shoreline.

Broadkill Beach differs from the other beaches studied, being a wide, continuous band consisting almost entirely of clean sand and small (<2 cm) gravel. Sediment depths are greater than 30 cm in most sections. The beach is currently protected by a series of regularly-spaced breakwater structures extending from high on the beach, out into the water at right angles to the shoreline. Shoreward, the beach is backed by varying widths of sparsely vegetated dunes, and a dense residential area. **Figure 3, Appendix A** is an aerial photograph of the study area, taken in 1997. This is the latest georeferenced photograph of this area currently available from the Delaware Department of Natural Resources. This beach is the southernmost of the beaches studied and is approximately 42 km (26 miles) from Port Mahon.

The two study transects sampled on Broadkill beach during this study were "North", and "South", whose upper (high beach) ends were located at N38°49.961', W075°12.958' and N38°49.713', W075°12.692', respectively. Locations of these points are shown on **Figure 3, Appendix A.** Approximate distance between the two transects was 577 m (1,894'). These transect sites were selected after a preseason assessment of the entire beach frontage. They were visually representative of all frontage examined, and were reasonably close to public access points.

Sampling procedures In Delaware Bay, *Limulus* spawning activity seems to be more intense during the full and new moon tides (Rudloe 1985). During the 2001 spawning season, full moon tides were on May 7; June 5; July 5, and new moon tides were on April 23, May 22; June 21. I sampled the beaches 2–4 days after each of these tides. It was not possible to sample all three beaches on a single day. Typically, the Kelly Island and Port Mahon samples were taken on one day, and Broadkill was sampled another day. For simplicity in this report, sample dates are listed as a single date (the day Kelly Island and Port Mahon were sampled), rather than two. Sample dates were April 26; May 10, 25; June 11, 25; July 9. On these dates, I sampled each beach along two transects which were at right angles to the waterline. Upper (high beach) transect endpoints were located by reference to permanent visual markers, and recorded as GPS readings, and the same section of beach was sampled on each date. (The exception to this sampling schedule is that I could not sample the Kelly Island N transect on 25 May because the boat sank at anchor while I was collecting the sample on S transect.) All transects were within the intertidal zone, where spawning activity is more concentrated (Botton, et al. 1994, Shuster and Botton 1985, Weber and Ostroff 1997, Williams 1986, Williams 1987).

On sample dates, I took 25 evenly-spaced core samples along each transect. Each transect spanned 83% of the distance from the nocturnal high tide wrack line down toward the foot of the beach, where the flat began. The nocturnal high tide wrack line was used as the upper end of transects because nocturnal tides around the new and full moons (when spawning is believed to be heaviest) are higher on the beach than diurnal high tides of the same period. I used 83% of the total distance from the nocturnal tide wrack line because a pilot study I did in 2000 (unpublished) showed that 100% of all egg clusters in each of four Delaware beaches were located in the upper 83% of the nocturnal-tide-wrack-line-to-flat span. In that study, 10 continuous trench transects, each running from nocturnal wrack line down to the tide flat, were made on each beach. Egg clusters present in every one-foot span of each trench were hand counted and recorded. The results showed clearly that the beaches studied had similar cluster distribution profiles. Cluster numbers were low near the wrack line, rose to maximum abundance near the upper mid beach, then decreased in numbers toward the lower end of the beach. No clusters were found in these beaches past the 83% point mentioned above.

Although intertidal beach spans varied at the points where transects were located, the 25 sample cores along each transect were kept evenly, thus proportionally, spaced across the sample distance by use of transect lines made from bungee cord. These lines were marked off into 25 equal units of distance. Bungee cord lines can be stretched to fit beaches of varying widths, and since the marks spread apart at the same ratio as the line is stretched, cores are always equally spaced across the span to be sampled.

Sample cores consisted of beach sediment cores, 5.7 cm (2.25") in diameter x 20 cm (8") deep. The 20 cm depth of the sample cores spans the reported range at which most egg clusters are placed during spawning (Hummon et al. 1976, Rudloe 1979, Weber 1998, Weber 1999a, Weber 2000). Surface area (cross section) of each core was 25.65 cm^2, giving a total cross-section of the 25 cores taken per transect of 641 cm^2. After each core was lifted, it was separated into two fractions: 0–5 cm and 5–20 cm depth. This was done by sliding a sheet metal divider through a transverse slit in the corer, located 5 cm from its top end. The divider was held in place until the lower, 5–20 cm, portion of the core had been dumped through a screen into the first sample bucket, then was removed so the 0–5 cm portion could be put through a screen into the second bucket. These core fractions are of interest because shorebirds forage in the surface sediments, while the clusters are deposited somewhat deeper. Knowledge of egg numbers present in the 0–5 cm part of a beach is therefore useful in estimating how many *Limulus* eggs are potentially available for shorebird use.

Core sample fractions from each transect were combined into the appropriate bucket as they were collected, and all of the sediment material collected was processed to extract the eggs. Upon collection, each fraction of the core sample was passed through a 13 mm (0.5") mesh screen into a collection bucket, to remove any large gravel or shells, and to reveal clumps of eggs. (When *Limulus* eggs are laid, they adhere together in tight clusters [Rudloe 1979], and they continue to adhere tightly to each other during the first weeks of development.) One, or more, tight aggregations of eggs that did not pass through the 13 mm mesh was recorded as a single cluster. Thus, a single 20 cm core could have up to two clusters: one each from the 0–5 cm and 5–20 cm fractions. After being recorded, clumps were broken apart to pass through the 13 mm screen, into the appropriate sample container, and their component eggs included in the final egg volume values. The 25 sample cores from a single transect (0–5 cm and 5–20 cm fractions, considered together) had a total volume of approximately 13.3 liters (3-1/2 gallons).

Extracting and quantifying eggs Samples were processed at the Delaware National

Estuarine Research Reserve Center, on Kitts Hummock Road, south of Dover, DE. The contents of each bucket were flushed through a series of screens with running water to separate eggs from most of the beach substrate material. Mesh size of the first screen was 6.4 mm (1/4"); of the second, 3.2 mm (1/8"). All eggs were captured on the third screen, of copper window screening (mesh size, 1 x 1.5 mm = 0.04" x 0.06"), which retained all eggs encountered, plus beach sediment particles in the same size range. Eggs were separated from the remaining sediment and most other materials retained on the third screen, by elutriation with running tap water as described previously (Weber 1998).

Residual peat particles and meiofauna were separated from *Limulus* eggs, embryos and trilobite larvae by hand picking. I then used a 10% (v/v) solution of $MgSO_4$ and tap water to separate smaller, greenish undeveloped eggs ("eggs") from the larger, visibly embryonated eggs ("embryos") by differential flotation. Viable "embryos" float, viable "eggs" sink, in this solution, giving a good separation. The separation is not absolute to the eye however, for some items that appear to be "eggs" float, while some apparent "embryos" sink. "Eggs" that float are not viable. Most hatchlings (trilobite larvae) swim, or float passively, in the $MgSO_4$ solution. All material that floated in the $MgSO_4$ solution was discarded, and only the viable eggs were quantified. It is not necessary to also quantify embryos and trilobite larvae, because the eggs take sufficient time to develop that they are present in the beach for at least two sample periods before they hatch. (See **Beach temperature**, below.)

As each sample is being separated from remaining sediments by the elutriation process, a few viable eggs are also rinsed out. All material coming out of the elutriation system was checked, and any viable eggs present were hand counted. When sample egg numbers were small, I made direct counts. When egg numbers were too great for direct counting to be efficient, I measured the extracted eggs volumetrically, using standard graduated cylinders. Volumes were measured by pouring the sample, with tap water, through a funnel into a graduated cylinder (25, 50, 100, 250 and 500 ml, as appropriate to sample size). The cylinder was then stoppered, inverted several times to distribute the sample evenly in the water column, set upright and allowed to settle. After settling, the cylinder was bumped against the benchtop several times to further consolidate the sample, then volume was read and recorded.

By counting measured volumes of eggs, some taken during each sampling period, I found there was an average of 178 eggs (n= 20 samples) per ml. Eggs used for these counts were taken from among those extracted from the core samples on each sample date. They were not selected from a single cluster, core, or transect. This correlates well with Shuster and Botton's (1985) report of 176 eggs/ml (n=9 samples from a single cluster). I used the average value 178 to calculate egg numbers from their respective volumes.

Results And Discussion

Beach temperature The time required for *Limulus* eggs to develop and hatch is controlled by ambient temperature. I measured beach temperatures within the transects on each date when core samples were taken. This was always near low tide, usually between 7 and 11 AM, so transects had been under the influence of air temperature and insolation for several hours prior to measurement. Readings were taken with digital probe thermometers at a depth of 20 cm, at the upper, middle, and lower end of each transect. On several transects, subsurface rock, shell, etc., required that some readings be taken at less than 20 cm, however, no readings were taken at less than 10 cm.

There was little variation in beach temperature within or between transects. On 26 April, during the first sampling, average temperature of the 3 beaches was 12.9°C (55.6°F). Average beach temperatures increased steadily through the sampling period to 23.0°C (73.8°F) on the last sample date (9 July). This is an average increase of ≈1.8°C (≈3.2°F) per week of the study period. In the laboratory, French (1979) found that *Limulus* eggs took more than 6 weeks to hatch at 15–17°C (59–63°F), and 3–4 weeks to hatch at 25°C (77°F). This suggests that eggs laid within the study transects both before sampling began, and during the course of this study, were present in the sand for sufficient time to be sampled at least twice.

Egg clusters and total egg population The summer's sampling yielded considerable information about egg populations on the sampled beaches. I found a combined total of 43 egg clusters on the Kelly Island and Port Mahon transects during the 2001 sampling period. No clusters were ever found on Broadkill Beach, although a few dispersed eggs were regularly recovered. The number of clusters found in any single transect on one sampling date ranged from 0 to 7 (for Port Mahon, south transect, on 11 June). For purpose of illustration, 7 clusters per transect would equate to 109.2 clusters per m^2. **Figure 4** shows the distribution of total egg clusters by sampling date. There were no clusters from any transect on the first sampling date, and only four clusters on the last sampling date, indicating that the sampling season spanned the period of heaviest spawning. Thus, data collected during this study should be representative of *Limulus* spawning on these transects during the 2001 spawning season.

Table 1 shows beaches and transects ranked by total numbers of egg clusters, and compares the 2001 season's cluster totals observed on the Port Mahon N and S transects to totals from previous years. No earlier data exists for Kelly Island because it has not been sampled previously. Cluster totals from previous years on Port Mahon are not directly comparable to the 2001 values, since the 2001 season sampling was done at right angles to the water line, and in previous years was done parallel with the water line. This change was made because the parallel sampling procedure used previously yielded eggs/m^2 values higher than were actually present over the whole intertidal spawning area. The 2000–1998 cluster totals are included to allow direct year-to-year comparisons during that period.

All clusters were in the 5–20 cm fractions of cores, except for one cluster found in the 0–5 cm fraction on Port Mahon N on 11 June. Of interest is the fact that in 2001 Port Mahon S had approximately twice as many clusters as Port Mahon N (**Table 1, Appendix B**). The previous year, both Port Mahon transects had nearly equal numbers of clusters, and in 1999, total clusters were highest on Port Mahon N. It is tempting to attribute the changes in egg cluster numbers observed on these transects, in each of these three seasons, to qualitative changes in the beach associated with erosion. However, that is not possible, in part because correlated sand depth and beach sediment studies have not been done on this beach.

The total number of eggs found in any single transect on one sampling date (0–5 cm and 5–20 cm fractions combined) ranged from 0, to 122,000 (Port Mahon N, 11 June). For purpose of illustration,122,000 eggs per transect would equate to 1,900,000 eggs per m^2. **Table 2 (Appendix B)** ranks the transects by total number of eggs collected during the 2001 season. For these beaches and transects, the ranking by total egg numbers is the same as the ranking by cluster totals, which is not always the case. Most eggs were in the 5–20 cm fractions of cores, but substantial numbers were also present in the 0–5 cm fractions. On Kelly Island and Port Mahon, eggs present in the 0–5 cm fractions ranged from 3% to 19% of total eggs collected (**Table 2**).

Broadkill beach, where no clusters were found, represents a curious case, since considerably more eggs were found in the 0–5 cm fractions than in the 5–20 cm fractions. The very high percentages of eggs found in the top 5 cm (N transect, 69%; S transect, 58%), and the very low total numbers of eggs found (**Table 2**), might suggest that many of the eggs found in the samples had washed down to this beach from more heavily used spawning beaches to the north. However, on the last sample date, I found an estimated hundred trilobite larvae in the 5–20 cm fractions from both transects. These, and the eggs found in the 5–20 cm fractions verify that some spawning did actually take place on these areas of Broadkill beach, since eggs will not become reburied into beach sediments after they have come up out of the sand. This fact was noted by Williams (1986), and is the basis of most methodologies used to separate *Limulus* eggs from beach sediment samples.

There are two components to the *Limulus* egg population in a beach: clusters as laid by spawning individuals, and the subsequently-dissociated eggs dispersed throughout beach sediments. Both these components must be sampled, and the resultant total egg volume quantified, to obtain the most accurate estimate of transect (and thus beach) egg load. Because dissociated eggs are present throughout the spawning season, a simple census for egg clusters only will seriously underestimate actual egg numbers present. Conversely, excluding egg clusters from total egg volume calculations would also underestimate egg numbers. In this study I enumerated clusters as they were found in the sample cores, using the 13 mm (0.5") screen. Then I replaced their component eggs into the samples so they would be included in the total egg population. Finally, I extracted all eggs from the entire quantity of material collected in the sample cores.

If it is assumed that clusters in this study contained the same number of eggs per cluster, 3,650, reported by Shuster and Botton (1985) for a study of Delaware Bay beaches, it is possible to estimate the fractions of eggs that were represented in clusters in this study. If the total number of clusters found on Kelly Island and Port Mahon during the 2001 sampling is multiplied by 3,650, and the resulting value is divided by the total eggs found on each beach, then only 23.1% (Port Mahon) and 40.6% (Kelly Island) of the eggs collected on these transects would have been contained in the clusters. Thus, dispersed eggs were substantially more abundant on these transects than the number of clusters would indicate. Moreover, these estimated percentages are likely to be high because complete clusters are seldom recovered with core sampling, and therefore the true percentages of eggs found in clusters during this study would be lower.

Kelly Island, Port Mahon and Broadkill beaches varied widely from each other in their transect total egg numbers for the sampling season. **Table 3, Appendix B** compares their season transect egg totals to season transect egg totals observed on Kitts Hummock, Pickering, and North Bowers beaches, which were also studied during 2001, in a parallel study. The Port Mahon transects had approximately twice as many total eggs as transects on the next most populous beach, Kitts Hummock (248,000). In turn, Kitts Hummock and Pickering (201,000) beach transects yielded more eggs than did those on Kelly Island. Pickering was approximately twice as productive as Kelly Island (104,000). North Bowers had approximately half as many eggs as Kelly Island (55,000). Broadkill beach had a season total from both transects of 431 eggs.

Evaluation of spawning habitat and 2001 beach egg loads *Limulus* eggs clusters and eggs are not distributed evenly across the intertidal area, but instead are more frequent at about mid span. The vertical sample transects used in this study passed through all intertidal areas where eggs were present. This has the effect of summing differing egg densities across the span sampled. In turn, this allows egg load data to be reduced to an average per-square-meter value which should be representative of any other square meter of spawning habitat in the immediate area. In this study, "spawning habitat" was defined as the area from the nocturnal high tide wrack line down toward the low water line, 83% of the distance to the beginning of the tide flat. Average-per-square-meter egg density values obtained from vertical transect sampling can be used to calculate estimates of beach egg load based on *length* of spawning habitat shoreline. The process is to multiply a transect's average eggs/m^2 value by the transect's length, then use the resulting value to multiply the meters of shoreline on that beach. As can be seen from data presented above, the full length of a beach may have a variable egg load. In fact, differences between total N and S transect egg loads are commonplace. For this reason, I used the average of the total eggs per transect in these calculations (0–5 cm and 5–20 cm fractions combined). In order from north to south, each of the study beaches is discussed below, with an estimate of its season total egg load. **Table 4, Appendix B** provides egg load estimates for each of the study beaches, which are discussed individually, below.

Kelly Island I walked 2,203 m (7,234') of frontage on this shoreline, to determine the amount of spawning habitat present. I began at the southern tip of Kelly Island, at the first section of sand with sufficient depth for spawning (N39°11.577', W075°23.781'), and continued northward along the storm wrack line to N39°12.872', W075°23.855. I used a GPS unit to record the lengths of sand stretches having sufficient depth for spawning. Center widths of these stretches were measured with a tape, so estimates of their surface areas could be also be calculated. There were 901 m (2,957') of spawning habitat along this 2,203 m (7,234') of bay frontage. This represents 40.8% of the length I examined. The combined area of these sections of spawning habitat was 0.39 hectare (0.96 acre). The 2001 estimated egg load for the 901 m spawning frontage of the 2,203 m examined, based on the calculations described above, is 3.2 x10^9 eggs **(Table 4, Appendix B).** Spawning frontage is shown in **Figure 1, Appendix A**.

Owing to the error mentioned earlier, the span of shoreline I examined extended from near the present south tip of Kelly Island to considerably north of the proposed restoration project. It was possible to calculate the percentage of spawning habitat that was within the limits of the proposed project. There were 933 m (3,062') of shoreline from the southern tip of Kelly Island to the northern limit of the proposed project. Within this span, there were 466 m (1,531') of spawning habitat. This represents 49.9% of the total span I examined. The combined area of the sections of spawning habitat within this span was 0.20 hectare (0.49 acre). The 2001 estimated egg load for the 466 m spawning frontage of this part of the shoreline, based on the calculations described above, is 0.83 x10^9 eggs **(Table 4, Appendix B).**

This is the first time Kelly Island has been evaluated as a *Limulus* spawning site. Judging from the evidence of a rapidly eroding shoreline—both on-site, from aerial photographs, and from the relevant USGS Quadrangle (1956)—the spawning habitat I evaluated in 2001 will very likely be altered before the next spawning season by erosion. Indeed, the impression gained from repeated sampling on the beach, and walking along the storm wrack line, is that this shoreline is not at all a constant or consistent spawning area. Some indication of recent changes along this shoreline can be obtained by simply noting the westward displacement of the sandy spawning areas I found in 2001 from the stretches of sand shown in the 1997 aerial photograph **(Figure 1, Appendix A)**. The rate of erosion has been variable, as shown by the varying distances between lines indicating 2001 spawning habit, and the sandy stretches present in 1997.

It seems likely that some stretches of the Kelly Island shoreline with sand deep enough to be suitable for spawning in 2001 will still have enough sand next year. However, it is also likely that some stretches of shoreline suitable for spawning in 2001 will not be suitable next year. Further, some sections without any sand, or without a suitable depth of sand in 2001, could possibly have enough sand next year to support spawning. These are reasonable beliefs when the stretches of spawning habitat I found in 2001 are compared to the stretches of sand visible on the 1997 aerial photograph upon which they are plotted **(Figure 1, Appendix A)**. Stretches of spawning habitat appear and disappear in response to continuing erosion of the shoreline. With reference to the 1997 photograph, in some places long stretches of sand present then are now gone. Other sandy spawning areas I found along those same sections of shoreline in 2001 are reduced in total length from stretches of sand visible in the photograph. Along some other sections of the shoreline, where no sand was visible in 1997, there was enough sand present in 2001 that spawning occurred.

Such comparisons must be made tentatively because the sandy stretches visible in the 1997 photograph were not checked to see how much spawning occurred on them. For Kelly Island, there is only the 2001 *Limulus* egg sampling and spawning habitat evaluation data, coupled with the understanding that spawning only occurs on sandy substrates. I have not observed *Limulus* to spawn in mud or peat substrates on any beach I have studied in Delaware. My experience in sampling Delaware beaches over the past four years is that they also do not spawn on beaches with only a shallow layer of sand (< 10 cm) over mud or peat. For this reason, stretches of sand shown in an aerial photograph do not necessarily indicate suitable spawning habitat.

Port Mahon I examined the entire 1,672 m (5,491') frontage of the beach at low tide, to determine the amount of spawning habitat present. I began at the southern end of the beach (N39°10.654' W075°24.491') where a culvert passes under the road, and continued northerly to N39°11.358', W075°23.909' at the bait store. I used a GPS unit to record the waterline lengths of sand stretches with sufficient depth for spawning. At the same time, center widths of these stretches were measured with a tape, so their approximate surface areas could be calculated. There were 450 m (1,478') of spawning habitat along the beach. This represents 26.9% of the total length of Port Mahon beach. The combined area of these lengths of habitat was 0.44 hectare (1.08 acre). The amount of spawning habitat on this beach has remained essentially the same since I examined it in 1999. At that time, total area of spawning habitat was 0.39 hectare (0.96 acre), and 28.5% of total beach length (Weber, 1999b). The 2001 estimated egg load for the 450 m spawning frontage of this beach, based on the calculations described above, is 22.3 x10^9 eggs **(Table 4, Appendix B).** Spawning frontage is shown in **Figure 2, Appendix A.**

Typically, Port Mahon transects have been among the top transects for total numbers of *Limulus* eggs. **Table 5, Appendix B** compares total egg numbers from the Port Mahon N and S transects over three years, during which period, season total egg numbers for the beach have ranged between 400,000 and 500,000, while per-transect season total values have been 174,000 or higher. The 2001 total egg values from Port Mahon transects S and N, 268,000 and 233,000 respectively, were considerably higher than from any other transect sampled in a parallel study of other Delaware beaches done that same season. The next highest 2001 egg total observed was from Kitts Hummock S (135,000 eggs). In 2000, total egg values from Port Mahon transects N and S were 174,000 and 229,000, respectively. These were less than the value observed on Ted Harvey S (312,000) that year. The 1999 Port Mahon transect totals were both higher than any others, with the next highest 1999 total being Ted Harvey S (140,000).

Comparing the *Limulus* egg data from Port Mahon beach with similar data collected on other beaches sampled in this, and earlier, studies is problematic. For example, the approximately mile-long frontage of Port Mahon contains a rather small percentage of shoreline where there is sufficient sand to allow spawning, and where coupled *Limulus* pairs come up to the water's edge. While other beaches generally provide a meter of spawning beach for each meter of shoreline, this is definitely not the case at Port Mahon. It seems probable that female *Limulus* in the waters along Port Mahon beach are forced to concentrate into the few areas where they can spawn. This seems unlikely to be the case on most other beaches where shoreline and suitable spawning habitat are essentially equal. While the N and S transects typically have high cluster and total egg counts, these may be high simply because individuals spread along the Port Mahon shoreline are forced to come to the same few locations suitable for spawning. This could account for the high cluster counts and total egg numbers observed there. However, this concentration effect is partly offset by the fact that *Limulus* are legally harvested from Port Mahon beach two days a week, during the spawning season.

Personal observations, and discussions with those harvesting, suggest that females coming onto the beach to spawn are the primary catch. These potential spawners are taken before they have a chance to lay eggs, since females full of eggs are more desirable as bait, their intended use. No data are available on the percentage of spawning females harvested from this beach each season, but the favored places to harvest are the few spawning areas, which include areas surrounding both the N and S transects. A further confounding factor for Port Mahon spawning areas is the fact that large numbers of *Limulus* adults, of both sexes, become accidentally wedged into interstices between rocks of the riprap shoreline erosion barrier. Some individuals are trapped during each spawning event. Many of these animals become so firmly wedged between rocks that they cannot get free. Gulls prey on the more accessible individuals; the others die of exposure or starvation.

Broadkill The area I evaluated began at N38°50.347', W075°13.493' and continued southward to N38°48.408', W075°11.397', at the boundary with Beach Plum Island Nature Reserve. Total frontage length, 4,723 m (15,506'), was determined by measurements taken from beach restoration project plans provided by USACE personnel. At 13 locations distributed along the frontage, I measured beach width from nocturnal tide wrack line down to the foot of the beach slope. Widths for Broadkill beach ranged from 11.9 m (39') to 16.1 m (53'), with an average width of 14.4 m (47'). Frontage length of the beach was multiplied by the average width value to estimate the amount of spawning habitat present. The full length of shoreline consisted of sandy sediments, which appeared suitable for *Limulus* spawning. The potential spawning habitat on the beach was 6.4 hectares (15.8 acres). The 2001 estimated egg load for the 4,723 m of spawning frontage on this beach, based on the calculations described above, is 0.25 x10^9 eggs **(Table 4, Appendix B).**

In terms of beach slope and sediment size distribution, the entire shoreline of Broadkill beach appears to be equally suitable for spawning. However, only low numbers of eggs were found there during this study. It is unclear why this is so, although I usually found the wave height, and corresponding surf, to be greater than found on more northerly Delaware beaches on the same day, and within an hour or two. This surf difference may be attributable to influence of ocean waves. On more northerly Delaware Bay beaches, *Limulus* spawning does not take place when onshore winds create waves over ca. 30 cm (12") (personal observation). Waves observed on Broadkill during sampling periods were frequently over 30 cm high, and on several occasions, were ca. 50 cm (20") high. Whatever the cause of the low egg numbers on Broadkill beach, the extremely low numbers indicate that it currently receives very little *Limulus* spawning.

Acknowledgements

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APPENDIX A

Figure 1 Aerial photograph of Kelly Island, taken in 1997, showing locations of 2001 study transects N and S. Linear frontage of spawning habitat is shown in yellow. The horizontal, white line marks the northern endpoint of the proposed restoration project.

APPENDIX A

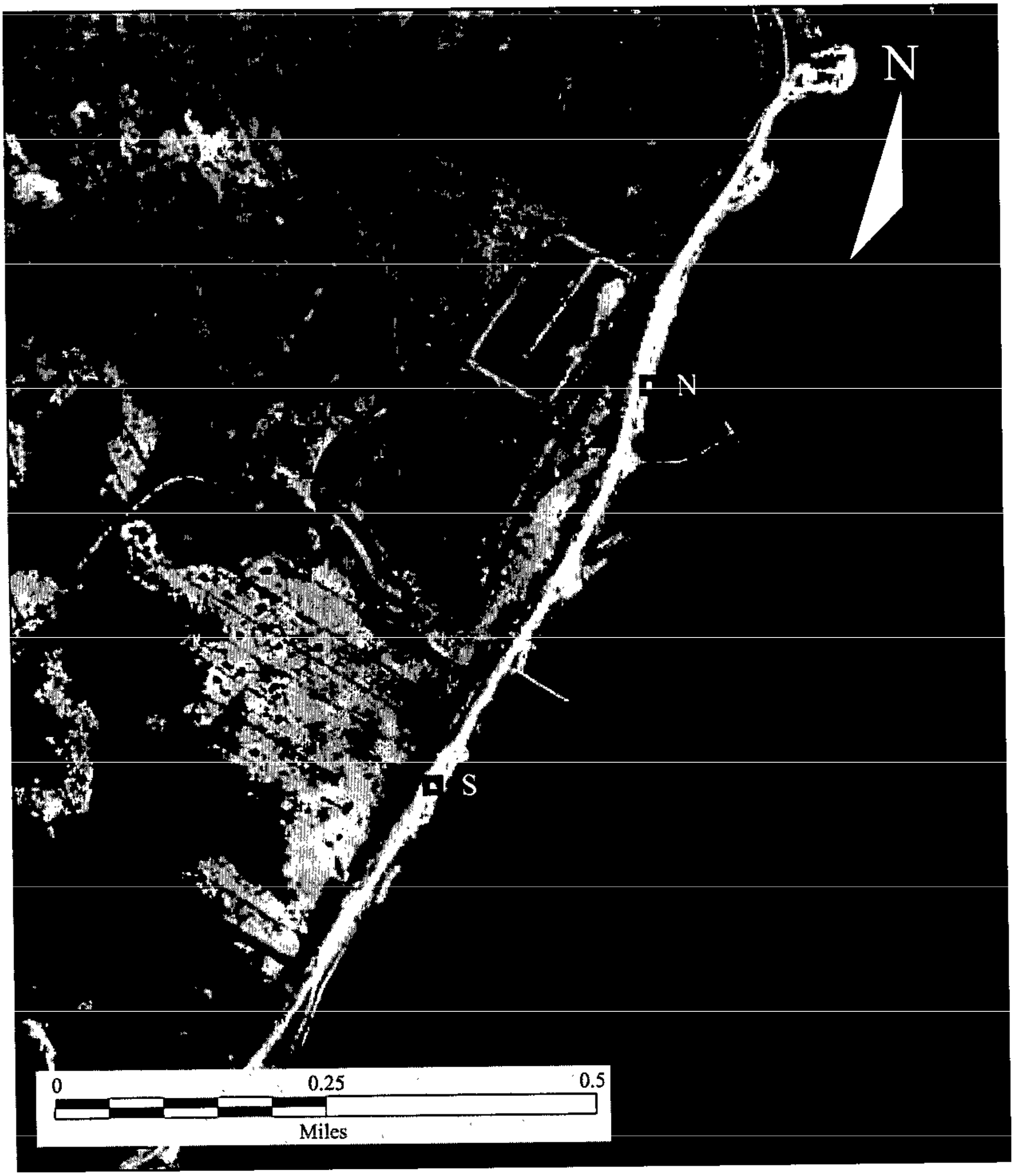

Figure 2 Aerial photograph of Port Mahon shoreline, taken in 1997, showing locations of 2001 study transects N and S. Linear frontage of spawning habitat is shown in yellow.

APPENDIX A

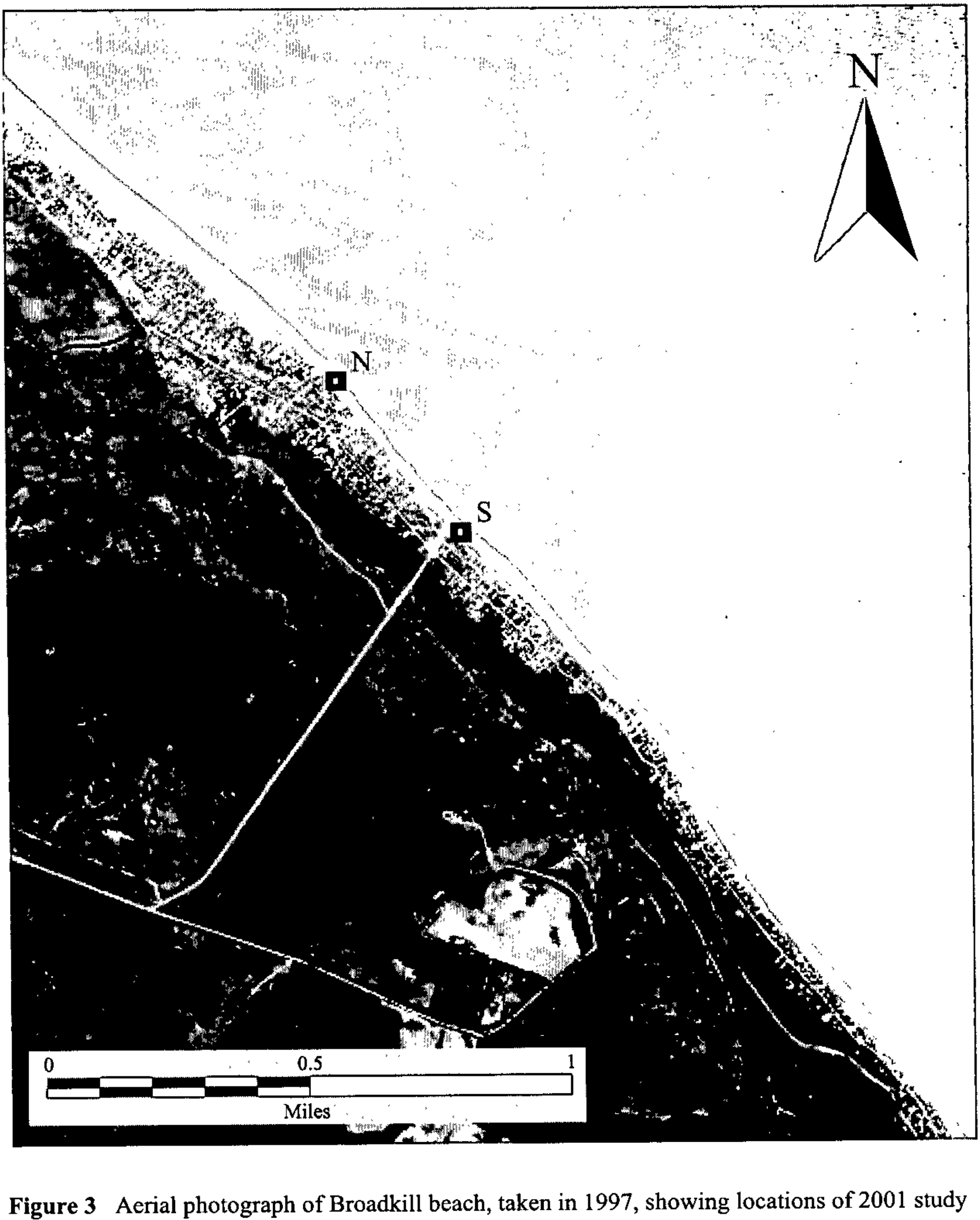

Figure 3 Aerial photograph of Broadkill beach, taken in 1997, showing locations of 2001 study transects N and S. The entire linear frontage of this beach is a continuous band of visually-similar spawning habitat.

APPENDIX A

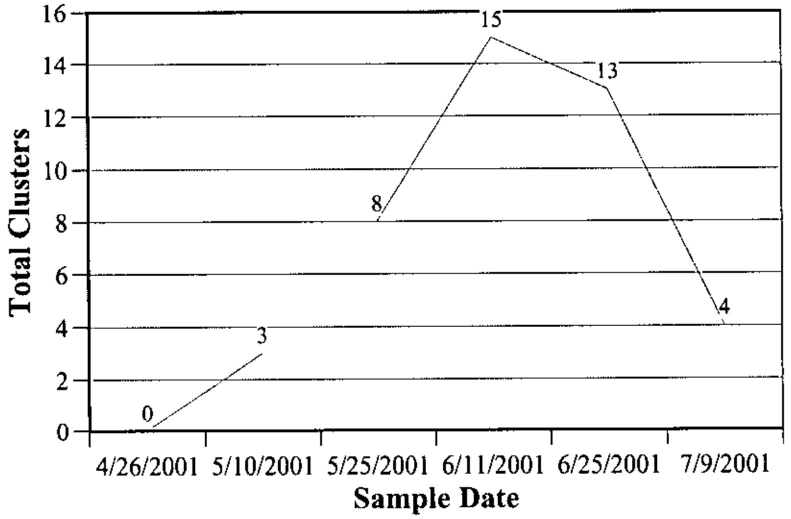

Figure 4 Distribution of the 43 egg clusters collected on Kelly Island and Port Mahon transects over the 2001 sampling period. No clusters were found on Broadkill beach. Values above dates are total clusters collected from all transects on that date

APPENDIX B

Table 1 Kelly Island and Port Mahon transects, ranked by total number of egg clusters found during the 2001 sampling period, with season cluster totals observed on Port Mahon during 2000 and 1999. The 2001 Port Mahon N and S transects are the same locations that were sampled in 2000 and 1999. Transect orientation was vertical in 2001, and horizontal in 2000 and 1999, so totals are not directly comparable. No clusters were found on Broadkill beach. The Kelly Island N total does not include a sample from 25 May, when only the S transect could be sampled, so the actual total would have been slightly higher.

	Total Clusters		
Beach & Transect	**2001**	**2000**	**1999**
Port Mahon, S	21	29	10
Port Mahon, N	11	25	27
Kelly island, N	8	—	—
Kelly island, S	4	—	—
Totals	44	54	37

Table 2 Kelly Island, Port Mahon, and Broadkill beach transects, ranked by total numbers of eggs found on transects in 2001. Values in the Total Eggs column are the sums of egg numbers extracted from all core samples taken in that transect during the season. Values in the 0–5 cm and 5–20 cm columns were obtained by various combinations of direct counts and volumetric extrapolations, so they have been truncated at the thousands level, except for Broadkill beach, where every egg was counted. The Kelly Island N total does not include a sample from 25 May, when only the S transect could be sampled, so the actual total would have been slightly higher.

Beach & Transect	Eggs, 0–5 cm	Eggs; 5–20 cm	Total Eggs	% in 0–5 cm
Port Mahon, S	18,000	250,000	268,000	7%
Port Mahon, N	44,000	189,000	233,000	19%
Kelly Island N	3,000	70,000	73,000	4%
Kelly Island S	1,000	30,000	31,000	3%
Broadkill S	223	102	325	69%
Broadkill N	61	45	106	58%

APPENDIX B

Table 3 Comparison of 2001 Kelly Island, Port Mahon, and Broadkill beach transect egg totals, to transect egg totals observed on Kitts Hummock, Pickering and North Bowers beaches during the same period. Values in the Total Eggs column are the sums of egg numbers extracted from all core samples collected from that transect during the season. Values in the 0–5 cm and 5–20 cm columns were obtained by various combinations of direct counts and volumetric extrapolations, so they have been truncated at the thousands level, except for Broadkill beach, where every egg was counted.

Beach	Eggs, 0–5 cm	Eggs; 5–20 cm	Total Eggs	% in 0–5 cm
Port Mahon	62,000	439,000	501,000	12%
Kitts Hummock	16,000	232,000	248,000	6%
Pickering	23,000	178,000	201,000	11%
Kelly Island	4,000	100,000	104,000	4%
North Bowers	2,000	53,000	55,000	4%
Broadkill S	284	147	431	66%

Table 4 Egg load estimates of Port Mahon, Kelly Island and Broadkill beaches, based on averages of beach N and S transect egg totals observed in 2001 (0–5 cm and 5–20 cm values combined). Spawnable Frontage is the combined length of all sections of spawnable shoreline frontage found on that beach in 2001. Egg Load Estimates were derived by multiplying Eggs /m^2 by Average Transect Length, then using the resulting value to multiply Spawnable Frontage. The Kelly Island N total does not include a sample from 25 May, when only the S transect could be sampled, so the actual egg total would have been slightly higher. The Kelly Island Project egg load estimate was calculated using Kelly Island values, for the shorter length of spawnable frontage within that section of shoreline.

Beach	Ave. Total Eggs per Transect	Eggs / per sq. meter	Ave. Transect Length (m)	Spawnable Frontage (m)	Egg Load Estimate
Port Mahon	250,500	3,906,118	12.7	450	22.3×10^9
Kelly Island	52,000	810,851	4.4	901	3.2×10^9
Kelly Island Project	52,000	810,851	4.4	466	0.83×10^9
Broadkill	216	3,368	15.9	4,723	0.25×10^9

APPENDIX B

Table 5 Total numbers of eggs found on Port Mahon transects in 2001 together with numbers found the preceding two seasons (0–5 cm and 5–20 cm values combined). Note that totals listed here for 2000 and 1999 represent only the eggs found, and do not include embryo numbers, as was done in reports for those years. Values have been truncated at the thousands level.

	Total Egg Numbers		
Beach & Transect	**2001**	**2000**	**1999**
Port Mahon, S	268,000	229,000	234,000
Port Mahon, N	233,000	174,000	239,000
Totals	501,000	403,000	473,000

PRE-CONSTRUCTION *SABELLARIA VULGARIS* BASELINE MONITORING AT BROADKILL BEACH SAND PLACEMENT SITE, SUSSEX COUNTY, DELAWARE

FINAL REPORT

Contract Number: DACW61-01-P-0291

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Introduction

The sandbuilder worm or "reefworm," *Sabellaria vulgaris* Verrill 1873 is a tube-building, annelid polychaete worm common on the Mid-Atlantic coastline of the USA (Gosner 1978, Lippson and Lippson 1997, Pollock 1998). This species ranges from Cape Cod to Georgia, occurring from low in the intertidal zone to shallow subtidal in waters with salinity above 15 ‰ (parts per thousand) (Gosner 1978, Ruppert and Fox 1988). Their life cycle includes a planktonic larval stage (Curtis 1973, 1975), and the larvae settle gregariously on a wide variety of substrata, including rocks and cobbles, clamshells, oyster bars, horseshoe crab carapaces, other worm tubes and pilings (e.g., Hidu 1978, Karlson and Shenk 1983).

Sandbuilder worm tubes are built of sand grains cemented together into a hard encrustation or rock-like structure. For feeding and tube construction, the worms protrude their crown of tentacles from the tube openings. Worm tubes may be found singly or in small clusters attached to various substrata. In Delaware Bay, sandbuilder worms are also found in dense aggregations where the tubes grow in straight, parallel, spaghetti-like bundles that completely cover the substratum (e.g., Wells 1970). These bundles may extend 20 cm or more above the substratum and be firm enough to walk on, often forming worm reef. The surface of the reef is of brown, honeycomb-like tube openings, each representing an individual sandbuilder worm. Reef development appears to be a unique characteristic of Delaware Bay populations, although Wells (1970) describes masses on a shipwreck in North Carolina that closely resemble Delaware reefs in consistency, morphology and tidal elevation.

From their sizeable reef structure and outward appearance, these aggregations are sometime known locally as "corals." This term is taxonomically inaccurate as well as potentially misleading, and it will not be used in this report. Reef-forming corals are members of another phylum (the Phylum Cnidaria, Class Anthozoa, in part, known as hermatypic corals) and characteristic of warm, clear tropical waters (Lalli and Parsons 1997). Because of their particular habitat requirements, true reef corals are not found in the Mid-Atlantic region. However, at least one species of non-reef forming, true coral, *Astrangia danae*, is found in the region in subtidal habitats though it has little tolerance for brackish water and high turbidity (Gosner 1978). Again, because of differing habitat requirements, this star coral *A. danae* is not associated with the sandbuilder reefs.

The ecology of sandbuilder worms has been studied in the region, and in the Delaware Bay in particular, in a number of studies over the past 30 years, for example, Amos (1966), Wells (1970), Curtis (1973, 1975, 1978), and Pembroke (1976). These sandbuilder reefs form a habitat that is far more physically stable (termed "worm rocks" by Gosner 1978) and ecologically diverse than would otherwise be found on bare rock or sand substratum. Thus, their reef structure and associated invertebrates are likely to provide food for fish and therefore represent a productive nearshore marine habitat.

The Army Corps of Engineers is proposing to use dredge material from the deepening of the Delaware River Federal Navigation Channel for shoreline restoration at

Broadkill Beach (USACE 1997). This area has been known historically (e.g., Curtis 1975) and recently (R. Martin, personal communication 2000, D. Miller, personal observation 2000) to have sandbuilder worm reefs. Since shoreline restoration has the potential to bury and disrupt these reefs, it is necessary to determine the extent and location of present reefs as baseline data prior to construction activities.

Purpose / Objective of Study

The purpose of this study is to document the presence, extent and locations of *Sabellaria vulgaris* colonies at Broadkill Beach in summer, 2001, with respect to habitat type, tidal stage, and other environmental factors.

Methods

A survey of the sandbuilder worm colonies at the Broadkill Beach sand placement site was conducted on 20 - 21 July 2001. Within an hour of the afternoon low water, the beach was walked by the contractor and his associates in two segments: on 20 July, from the north end at California Avenue south to Route 16, and on 21 July, from the boundary of Beach Plum Island State Park north to Route 16. These dates were chosen to be near the lowest spring tides of the month and represent the best opportunity for the colonies to be observed and measured in the intertidal and nearshore subtidal zones along this beach. The following operational definitions were used: a colony is defined as an aggregation of worm tubes, usually small in size (< 1 m across) and somewhat isolated from other worm tubes. A reef is defined as a larger structure, a meter or more across, with 5 cm or more of vertical worm tube growth.

Where sandbuilder colonies or reefs were observed, their location was determined with a handheld GPS (Garmin model GPSMAP 76) and associated with nearby streets or landmarks. The dimensions of the colony or reef, along the shore and distance seaward from the beach-slope break, were determined with a measuring tape. Various digital photographs of the whole reef, as well as close-up sections, were made to document the reef shape and structure. An on-site determination of the overall condition of the reef was made as indicated by new tube growth (tubes with a "flare" or "porch," Wells 1970), tube erosion, over-settlement by mussels or tube worms, crab burrows, *et cetera.*

Reef observations and notes were recorded in the field on data sheets (see below and included in appendices) and additional observations were made on the study area shoreline, especially where rock, cobbles and gravel were present at the tidal level typically associated with sandbuilder reefs. At the *Sabellaria* reefs and other sites along Broadkill Beach, additional measurements were made to more fully characterize environmental conditions in the study area. These included: seawater temperature and salinity (handheld YSI model 30 meter), beach slope (inclinometer), and sediment grain size (standard dry sieving methods).

Results

Three large *Sabellaria* reefs were found on Broadkill Beach: two on the rock groins at Alabama and at Georgia Avenues (both north of Route 16, Fig. 1), and another on the Old Inlet Jetty (2.4 km south of Route 16 and 800 m north of the Beach Plum boundary, Fig 2). Table 1 summarizes the location, description and photo documentation of these three reefs. All *Sabellaria* documented in this survey were associated with large rocks comprising the groins and jetty, and none was found along the sand beaches or wooden groins.

Alabama and Georgia Avenue groin reefs

These two reefs are triangular in shape and occupy the bayward end of the rock groins (Figs. 4, 6, and 7) at the north end of the groin field north of Route 16. Near the bayward end of the reefs, sandbuilder worm tubes covered nearly all of the rock surface (Figs. 5 and 8) and extended farther out, beyond visibility in the wave swash. The worm tubes were colonized by macroalgae and mussels, and new tube growth was noted at the Alabama Avenue reef (Fig. 5).

Old Inlet Jetty reef

The reef observed at the Old Inlet Jetty is by far the largest on Broadkill Beach (Figs. 10 - 14). The jetty extends an estimated 65 m bayward, and the reef on both sides occurs along the full length of the jetty (Figs. 10, 11, and 14) from 2 - 5 m from the beach slope break. Coverage at the bay-end is essentially 100% by sandbuilder worm tubes. In places along the reef, there are dense settlements of mussels, and new tube growth (Fig. 12) was noted.

Sand beaches and wooden groins

No sandbuilder worm colonies or reefs were found on the sand beaches in the study area (e.g., Figs. 3 and 15). These beaches consisted of sand or small gravel at the beach slope break where it was expected to find sandbuilder colonies. Wooden groins north (Fig. 9) and south (Fig. 16) of Route 16 were examined and found to be colonized by barnacles, oysters and some tubicolous epifauna. No sandbuilder worm colonies were seen on these structures.

Within the study area, bay water salinity ranged from 25 – 28 ‰, and temperature ranged from 24 – 26.5 °C (Table 2). Beach sediments ranged from fine to coarse sands that were typically well sorted except at Alabama Avenue.

Discussion

Sandbuilder reefs at Broadkill Beach and nearby sites

At Broadkill Beach, there are three sandbuilder worm reefs within a 3 km length of the beach. Their total plan area is estimated to be approximately 320 m^2, and all colonies were on the rocks of artificial structures. The Old Inlet jetty reef has an estimated area more than twice that of the groin reefs combined. According to Wells (1970), it is apparently this reef that is depicted in the photograph in Amos (1966). No sandbuilder worm colonies were found on the sand beaches that comprise the remainder of the shoreline in the study area.

Since fall of 1999, the contractor has observed and photographed sandbuilder worm colonies and reefs on sand beaches north of the study site at Slaughter Beach as well as south at Cape Shores in Breakwater Harbor, near Lewes.

Sandbuilder intertidal reefs in the lower Delaware Bay have been documented by Amos (1966), Wells (1970), Curtis (1973, 1975, 1978), Pembroke (1976) and Woodard (1978), ranging from Woodland Beach (Maurer and Watling 1973, cited in Pembroke 1976) to South Bowers Beach to the Inner Breakwater Harbor at Lewes (Wells 1970). In particular, Wells (1970) lists both the inlet jetty and Broadkill Beach as sites of well-developed reef masses. Curtis (1973) used the jetty as a site in his field experiments and reports of live colonies at nearby Beach Plum Island and Primehook Beach. Curtis (1975) also notes that intertidal colonies at Broadkill Beach are associated with firm substratum. Woodard (1978) studied Old Inlet Jetty populations and provides a photograph in her Plate 1. While the species ranges from Cape Cod to Georgia (Gosner 1978), the formation of reef structures seems unique to Delaware Bay (with a single documented exception in North Carolina, Wells 1970). Both historical studies and personal observation by the contractor show that intertidal sandbuilder colonies and reefs extend along the shoreline north and south of the Broadkill Beach study area.

The vertical distribution of sandbuilder colonies with respect to the tides is described by both Wells (1970) and Curtis (1975). At Big Stone Beach, Delaware, Wells (1970, Fig. 3) shows beach colonies bayward of the slope break, ranging from 0.0 to 0.35 m above mean low water (MLW). Curtis (1975) related the vertical distribution to exposure times during extreme spring tides at the Mispillion jetty sandflat. Almost no live worms were found above exposures of 175 minutes, and most of the live colony was found in the 101 – 150 minute exposure zone.

Beach sand near the reefs and elsewhere ranged from fine to coarse in grain size (Table 2). Sandbuilder worms are epifaunal and require water flow and wave action to provide sand grains for tube building. Broadkill Beaches are fully exposed to the Delaware Bay to the northeast and provide sufficient resuspension of sand to allow tube growth. Rees (1976) reported that sandbuilder worms from Big Stone Beach used coarse and medium sand to build tubes and employ increasing grain sizes with time.

Sandbuilder worm habitat in lower Delaware Bay

The distribution of the intertidal colonies and reefs of sandbuilder worm at Broadkill Beach is limited to artificial rock. At other beaches previously studied by the contractor, sandbuilder worm reefs are found on the sand beach near the beach slope break where cobble-sized or larger (i.e., ≥6.4 cm across, Gray 1981, Table 2.1, p. 13) natural stone, bricks or other construction debris are present at the beach slope break.

Shoreline dynamics and sediment sources for the lower Delaware Bay are discussed by Maurmeyer (1978). The lack of cobble at Broadkill Beach could be due to a lack of natural or artificial source or that coarse material has been removed or buried. Burial could have been facilitated by the sand trapping action of the groins currently on the Broadkill Beach.

Subtidal sandbuilder worms populations are more widely distributed both in Delaware Bay (Pembroke 1976, Fig . 1) and throughout this geographic distribution (Wells 1970, Gosner 1978). Sandbuilder worms inhabit a variety of hard-bottom communities, including the Bay's oyster beds (e.g., Maurer and Watling 1973) as well as the serpulid reefs located nearby offshore (e.g., Haines 1978, Haines and Maurer 1980a,b)

Sandbuilder worm life history

The life history of the sandbuilder worm in the lower Delaware Bay was extensively studied by Curtis (1973, 1975, 1978) and Pembroke (1976). Wells (unpublished and cited in Curtis 1975) noted that each winter there was a nearly complete kill of the sandbuilder worm adults in the intertidal region. Settling plate studies have found that sandbuilder larvae begin to settle from the plankton in late May or early June. Curtis (1973) extended these studies and reports (e.g., Curtis 1978) that larvae occur in the plankton from mid-April through October and settle in late May through October, with peaks in early summer and later in autumn. Persistence of the larvae in the plankton suggests that spawning occurs repeatedly in the April to October breeding season. Subtidal adults appear to have much higher survival rates and thus are the main contributor of the spring larvae. The intertidal colonies are settled in the spring by larvae spawned mainly by subtidal adults.

Curtis (1973) proposed that lunar or tidal spawning phasing and positive phototaxis were required to retain larvae in the region of the adults' habitat. Such a mechanism could account for the high sandbuilder abundances, settlement and reef formation in the Delaware Bay as opposed to the rest of the species' range. However, Pembroke (1976) investigated phototactic and geotactic responses of sandbuilder larvae and concluded that a light-dependent vertical migration was not capable of retaining larvae within the Bay. Eckelbarger (1975) reported gregarious settlement of larvae in laboratory experiments. Woodard (1978) concluded that subtidal and low intertidal worms contribute most heavily to the breeding population in Delaware Bay.

Sandbuilder worms have a persistent and well-documented distribution within the Delaware Bay. Subtidal populations appear to be more widespread and seasonally stable. Intertidal populations are more limited by availability of stable substratum and determined by seasonal recruitment and winter mortality.

Potential impacts of shoreline restoration and possible restoration options

Shoreline restoration at Broadkill Beach is anticipated to extend sand 67 m (220 feet) from mean high water to a depth of up to 2 m of sand. This will bury the groins and most of the length of the Old Inlet Jetty. Given that sandbuilder worms are sessile and tube dwelling, burial with substantial depths of sand will smother the worms and kill the intertidal colonies and reefs.

Analysis of the literature and recent observations indicates that sandbuilder worm populations (intertidal, but especially subtidal) are persistent and nearby, north and south of, Broadkill Beach. The habitat at Broadkill Beach is suitable for reef formation and intertidal populations, though limited to artificial rock structures by lack of cobble-sized or larger substratum on the beach at the beach slope break.

Sandbuilder colony and reef restoration options should focus on providing sufficiently stable rock substratum during the late May – October settlement period accessible to planktonic larvae from source populations. Accordingly, potential strategies include:

- Placing suitable substratum, large rock in groins or jetties or cobble-sized gravel on sand beaches at the 0.0 MLW tidal level during the summer months following shoreline restoration,
- Removal of the current reef masses to new shoreline locations to reconstruct or re-seed reefs via enhanced larval settlement,
- Reestablishing reefs by emplacement of colonized rocks from an extensive source population, e.g. that at the Mispillion jetty (Curtis 1975).

The efficacy of such restoration measures could be assessed in terms of the overall number or area of reef habitat created as compared to that presently occurring at Broadkill Beach. Successful establishment of new intertidal reef should be apparent as settlement, and new tube growth should be visible within a few months. It would also be useful to know the exact location and distance to the nearest intertidal and subtidal populations. Transport of sand away from the shoreline restoration site has the potential to impact naturally occurring sandbuilder worms at nearby beaches as well as subtidal populations. While outside the project limits, these populations are those most likely to provide larvae for settlement on emplaced, bare substratum. If sandbuilder worms can successfully out compete barnacles and mussels for intertidal rock surface, then it may be feasible to emplace substratum prior to the larval settlement period.

Conclusions

In a July, 2001 survey of Broadkill Beach, sandbuilder worm colonies were found in reef-like masses at three locations: two on the rock groins at Alabama and at Georgia Avenues, and the largest on the Old Inlet Jetty south of Route 16 and north of the Beach Plum Island boundary. At each location, sandbuilder reefs were associated with large rocks comprising the groins and jetty. No colonies were found along the beach near the beach slope break, low in the intertidal zone where they presently occur at nearby beaches in the lower Delaware Bay. In comparison with other sites studied by the contractor, sand beaches at Broadkill Beach lack the stable, cobble-sized or larger substratum to which colonies attach at nearby beaches. All colonies at Broadkill Beach are associated with large rocks on artificial structures.

Sandbuilder worms have a life cycle with a planktonic larval stage that permits broad dispersal. Larval settlement occurs over extended periods in the summer and early fall and is often gregarious. Stable substratum, for example gravel and rock of sufficient size not to be overturned by wave action, placed near mean low water should provide favorable habitat for sandbuilder worm settlement and reef development.

Sandbuilder worms are epifaunal and require water flow and wave action to provide food particles, oxygen and sand grains for tube building. While they have some capability to withstand burial under thin layers of sand, shoreline restoration would be expected to bury the present reefs at Broadkill Beach resulting in a substantial loss of this habitat. This impact could be compensated by placing suitable substratum, large rock in groins or jetties or cobble-sized gravel on sand beaches at mean low water during the summer or early fall following shoreline restoration. Other possibilities include removing current reef masses to new shoreline locations to reconstruct or reseed from enhanced larval settlement on the restored reefs.

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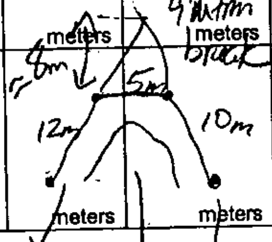
APPENDICES

Broadkill Data Sheet: Date 7/20 / Beach Segment NORTH / Observers Susannah Conrad Stephanie + Abigail Doug / Start 1300 / End ______

Time	Colony #	Lat + Long	Along-shore	Seaward Extent	Shape	% Cover & Substratum	Condition	Additional Samples	Comments
13:51	# —	38° 50.438 75° 13.593 (4.6m)	— meters	— meters	photo # 1 ☐ rectangular ☐ triangular ☐ scattered ☐ isolated ☐ at edges	___ % cover ☐ rock ☐ cobbles ☐ gravel ☐ sand ☐ mud	☐ mussels ☐ tubeworms ☐ crab holes ☐ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # sed sample bag or tube # beach slope 6 ° T 26.6 °C S 24.4 ‰	1st sand bar BN1
14:13	# —	38° 50.239 75° 13.304	— meters	— meters	photo # 2 ☐ rectangular ☐ triangular ☐ scattered ☐ isolated ☐ at edges	___ % cover ☐ rock ☐ cobbles ☐ gravel ☐ sand ☐ mud	☐ mussels ☐ tubeworms ☐ crab holes ☐ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # sed sample bag or tube # beach slope 8 ° T 25.8 °C S 25.3 ‰	gravel sample G2
14:29	#	38° 49.997 75° 12.966 10.1	6.3 meters	5.0 9 m from meters break	photo # 4-5 ☐ rectangular ☒ triangular ☐ scattered ☐ isolated ☐ at edges	50-100 % cover ☒ rock 60in ☐ cobbles ☐ gravel ☐ sand ☐ mud	☒ mussels +algae ☐ tubeworms ☐ crab holes ☒ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # sed sample bag or tube # beach slope 7 ° T 25.3 °C S 22.2 ‰	Sediment sample G3
14:42	#	38° 49.938 75° 12.911	 meters	meters	photo # (1) ☐ rectangular ☒ triangular ☐ scattered ☐ isolated ☐ at edges see sketch	edges only to 100 % cover ☒ rock 60in ☐ cobbles ☐ gravel ☐ sand ☐ mud	☒ mussels +algae ☐ tubeworms ☐ crab holes ☐ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # [✓ sed sample] bag or tube # beach slope 6 ° T 25.2 °C S 25.2 ‰	G4 angelwing 10cm thick

Notes: around margin no SV 4m from slope break

Sheet # ___ of ___ (form revised 20 July 2001)

Broadkill Data Sheet: Date 7/20 **/ Beach Segment** NORTH **/ Observers** _______________ **/ Start** __________ **/ End** =1600

Time	Colony #	Lat + Long	Along-shore	Seaward Extent	Shape	% Cover & Substratum	Condition	Additional Samples	Comments
15:08	wood piling + # groin	38° 49.876 75° 12.860 (4.8)	meters	meters	photo # _______ ☐ rectangular ☐ triangular ☐ scattered ☐ isolated ☐ at edges	_____% cover ☐ rock ☐ cobbles ☐ gravel ☐ sand ☐ mud	☐ mussels ☐ tubeworms ☐ crab holes ☐ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # ~~sed sample~~ bag or tube # beach slope 8 ° T 25.3 °C S 25.5 ‰	65
__:__	#	38° __.___ 75° __.___	meters	meters	photo # _______ ☐ rectangular ☐ triangular ☐ scattered ☐ isolated ☐ at edges	_____% cover ☐ rock ☐ cobbles ☐ gravel ☐ sand ☐ mud	☐ mussels ☐ tubeworms ☐ crab holes ☐ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # sed sample bag or tube # beach slope ____ ° T ______ °C S ______ ‰	
__:__	#	38° __.___ 75° __.___	meters	meters	photo # _______ ☐ rectangular ☐ triangular ☐ scattered ☐ isolated ☐ at edges	_____% cover ☐ rock ☐ cobbles ☐ gravel ☐ sand ☐ mud	☐ mussels ☐ tubeworms ☐ crab holes ☐ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # sed sample bag or tube # beach slope ____ ° T ______ °C S ______ ‰	
__:__	#	38° __.___ 75° __.___	meters	meters	photo # _______ ☐ rectangular ☐ triangular ☐ scattered ☐ isolated ☐ at edges	_____% cover ☐ rock ☐ cobbles ☐ gravel ☐ sand ☐ mud	☐ mussels ☐ tubeworms ☐ crab holes ☐ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # sed sample bag or tube # beach slope ____ ° T ______ °C S ______ ‰	

Notes:

Sheet # 2 of 2 (form revised 20 July 2001)

Broadkill Data Sheet: Date 7/21/01 / Beach Segment South / Observers Stephanie
Conrad Doug
Abigail / Start 1400 / End 1615

Time	Colony #	Lat + Long	Along-shore	Seaward Extent	Shape	% Cover & Substratum	Condition	Additional Samples	Comments
14:14	Christine #transect	38° 48.04 75° 11.383	— meters	— meters	photo # 1 ☐ rectangular ☐ triangular ☐ scattered ☐ isolated ☐ at edges	___ % cover ☐ rock ☐ cobbles ☐ gravel ☐ sand ☐ mud	☐ mussels ☐ tubeworms ☐ crab holes ☐ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # sed sample bag or tube # beach slope 6 ° T 26.6 °C S 26.5 ‰	S1
14:31	#	38° 48.743 75° 11.668	3-4 meters	65 est 5m from edge [illegible] ~20m meters	photo # 2 ☒ rectangular ☐ triangular ☐ scattered ☐ isolated ☒ at edges 100% [illegible]	10-100 % cover at end ☒ rock ☐ cobbles ☐ gravel ☐ sand ☐ mud	☒ mussels - dense ☐ tubeworms ☐ crab holes grass ☒ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # sed sample bag or tube # beach slope 5 ° T 26.8 °C S 25.7 ‰	S2 mussel sample
15:18	#	38° 49.150 75° 12.070	— meters	— meters	photo # 3 ☐ rectangular ☐ triangular ☐ scattered ☐ isolated ☐ at edges	___ % cover ☐ rock ☐ cobbles ☐ gravel ☐ sand ☐ mud	☐ mussels ☐ tubeworms ☐ crab holes ☐ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # sed sample bag or tube # beach slope 5 ° T 28.0 °C S 26.4 ‰	S3
15:46	#	38° 49.646 75° 12.586	— meters	— meters	photo # ___ ☐ rectangular ☐ triangular ☐ scattered ☐ isolated ☐ at edges	___ % cover ☐ rock ☐ cobbles ☐ gravel ☐ sand ☐ mud	☐ mussels ☐ tubeworms ☐ crab holes ☐ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # sed sample bag or tube # beach slope 7 ° T 28.0 °C S 20.0 ‰	S4

Notes: ✓

Sheet # 1 of 2 (form revised 20 July 2001)

Broadkill Data Sheet: Date 7/21 **/ Beach Segment** ______ **/ Observers** ______ **/ Start** ______ **/ End** ______

Time	Colony #	Lat + Long	Along-shore	Seaward Extent	Shape	% Cover & Substratum	Condition	Additional Samples	Comments
15:54	#	38° 49.701 75° 12.659	— meters	— meters	photo # ____ ☐ rectangular ☐ triangular ☐ scattered ☐ isolated ☐ at edges	____% cover ☐ rock ☐ cobbles ☐ gravel ☐ sand ☐ mud	☐ mussels ☐ tubeworms ☐ crab holes ☐ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # sed sample bag or tube # beach slope ____° T ____°C S ____‰	S5
__:__	#	38° __.____ 75° __.____	meters	meters	photo # ____ ☐ rectangular ☐ triangular ☐ scattered ☐ isolated ☐ at edges	____% cover ☐ rock ☐ cobbles ☐ gravel ☐ sand ☐ mud	☐ mussels ☐ tubeworms ☐ crab holes ☐ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # sed sample bag or tube # beach slope ____° T ____°C S ____‰	
__:__	#	38° __.____ 75° __.____	meters	meters	photo # ____ ☐ rectangular ☐ triangular ☐ scattered ☐ isolated ☐ at edges	____% cover ☐ rock ☐ cobbles ☐ gravel ☐ sand ☐ mud	☐ mussels ☐ tubeworms ☐ crab holes ☐ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # sed sample bag or tube # beach slope ____° T ____°C S ____‰	
__:__	#	38° __.____ 75° __.____	meters	meters	photo # ____ ☐ rectangular ☐ triangular ☐ scattered ☐ isolated ☐ at edges	____% cover ☐ rock ☐ cobbles ☐ gravel ☐ sand ☐ mud	☐ mussels ☐ tubeworms ☐ crab holes ☐ new Sv growth ☐ new Sv settlement ☐ eroding tubes ☐ vacant tubes	voucher jar # sed sample bag or tube # beach slope ____° T ____°C S ____‰	

Notes:

Sheet # 2 of 2 (form revised 20 July 2001)

FIGURES

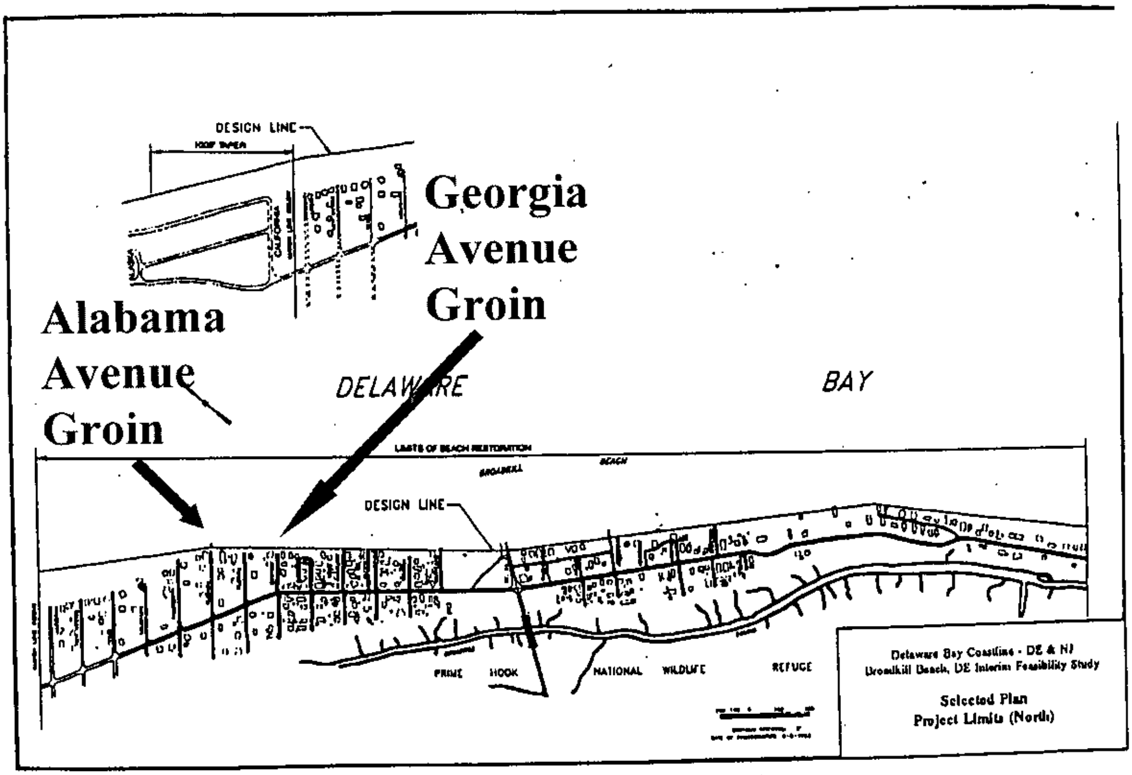


Figure 1. Location of Alabama and Georgia Avenue groin reefs.

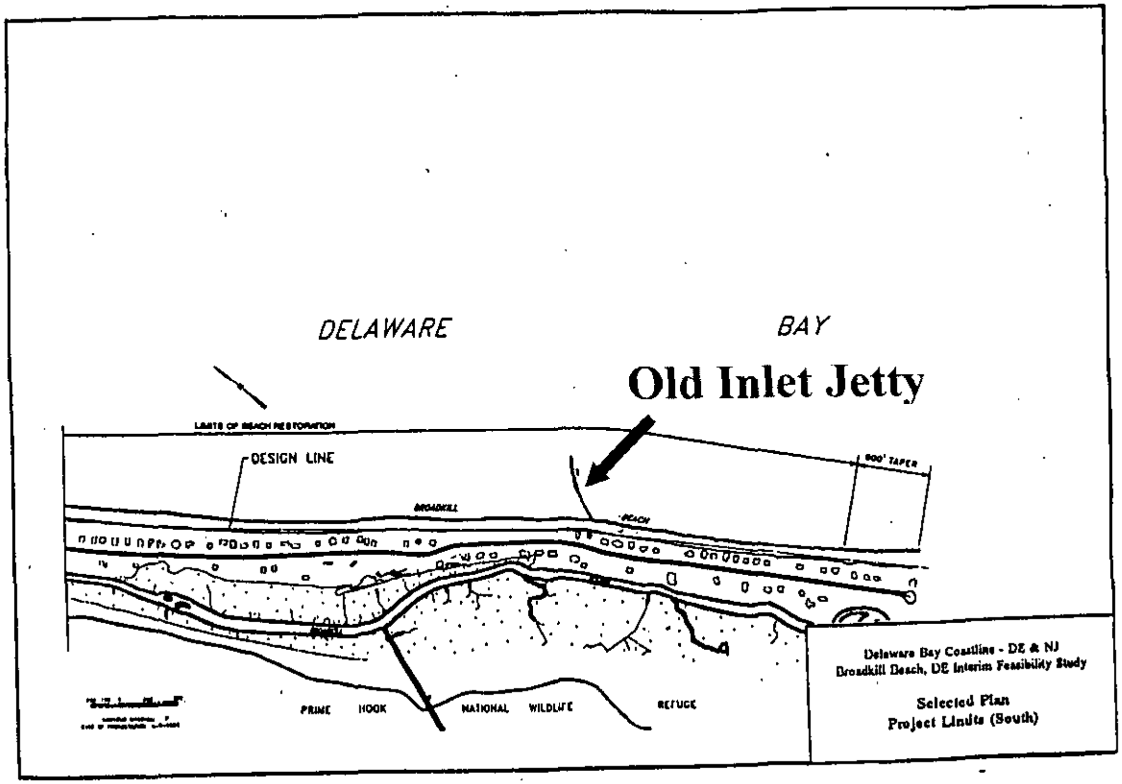


Figure 2. Location of Old Inlet Jetty reef.

Figure 3. Survey team for Broadkill Beach, 20 July 2001. Left to right: Stephanie Roberts (Howard U.), Abigail Bradley (U. Delaware), Susannah Karin (U. Delaware), Conrad Pilditch (U. Waikato). GPS Location: at north end of survey area, 38° 50.438′ N, 75° 13.593′ W.

Figure 4. Alabama Avenue groin, 20 July 2001, 38° 49.997′ N, 75° 12.996′ W. Wide photograph of the triangular reef at the bayward end of the rock groin.

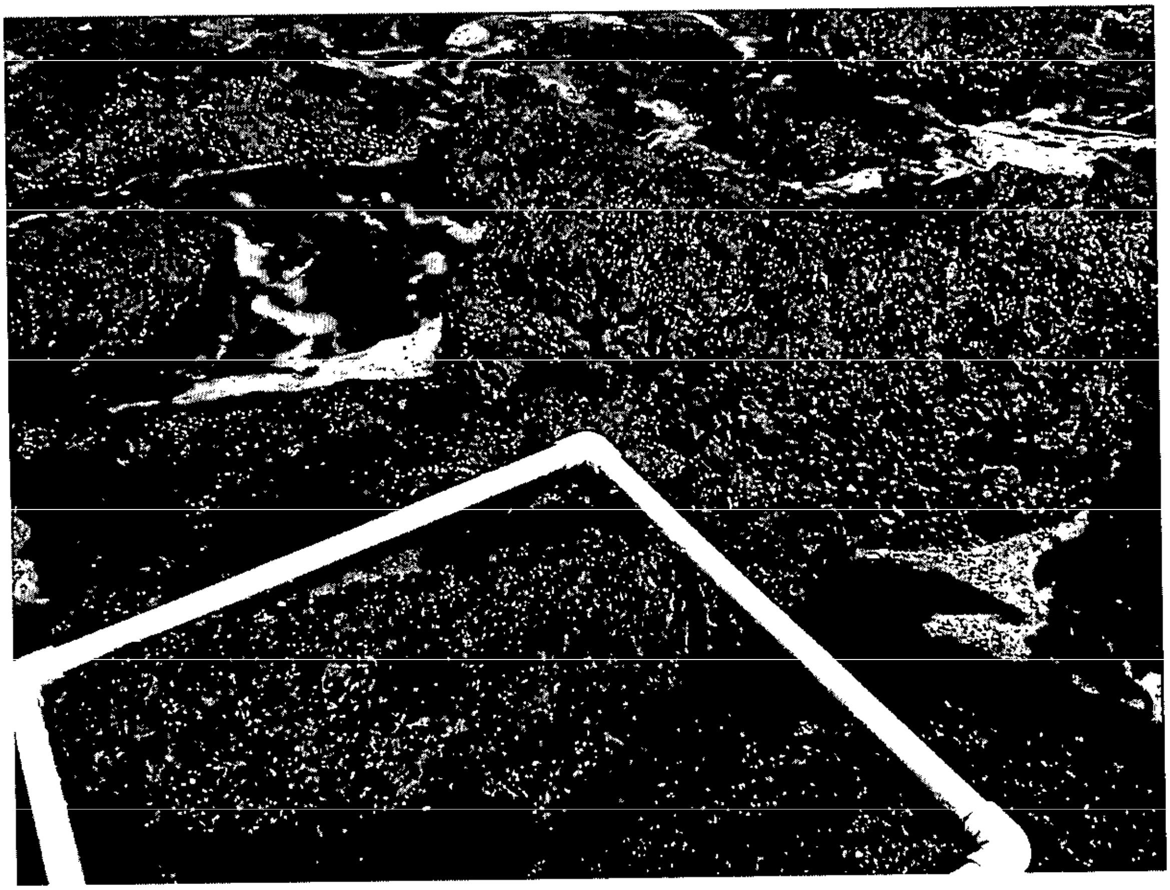


Figure 5. Alabama Avenue groin, 20 July 2001, 38° 49.997′ N, 75° 12.996′ W. Close photograph of rocks covered with sandbuilder worm colonies with 0.5 m x 0.5 m quadrat for scale. Note colonization by mussels and macroalgae.

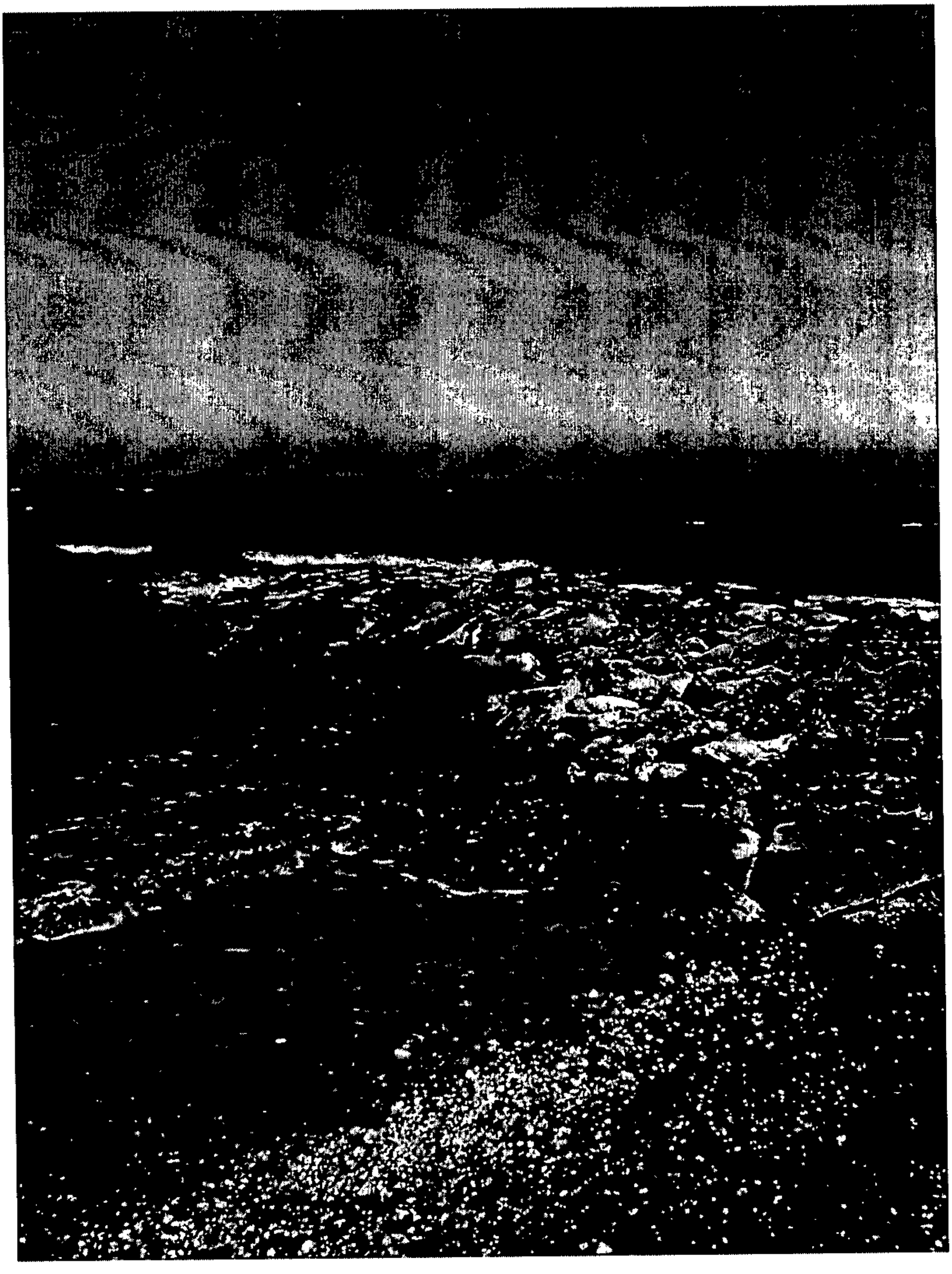


Figure 6. Georgia Avenue groin, 20 July 2001, 38° 49.938′ N, 75° 12.911′ W. Wide photograph of rocks covered with sandbuilder worm.

Figure 7. Georgia Avenue groin, 20 July 2001, 38° 49.938′ N, 75° 12.911′ W. Wide photograph of rocks covered with sandbuilder worm colonies with 0.5 m x 0.5 m quadrat for scale.

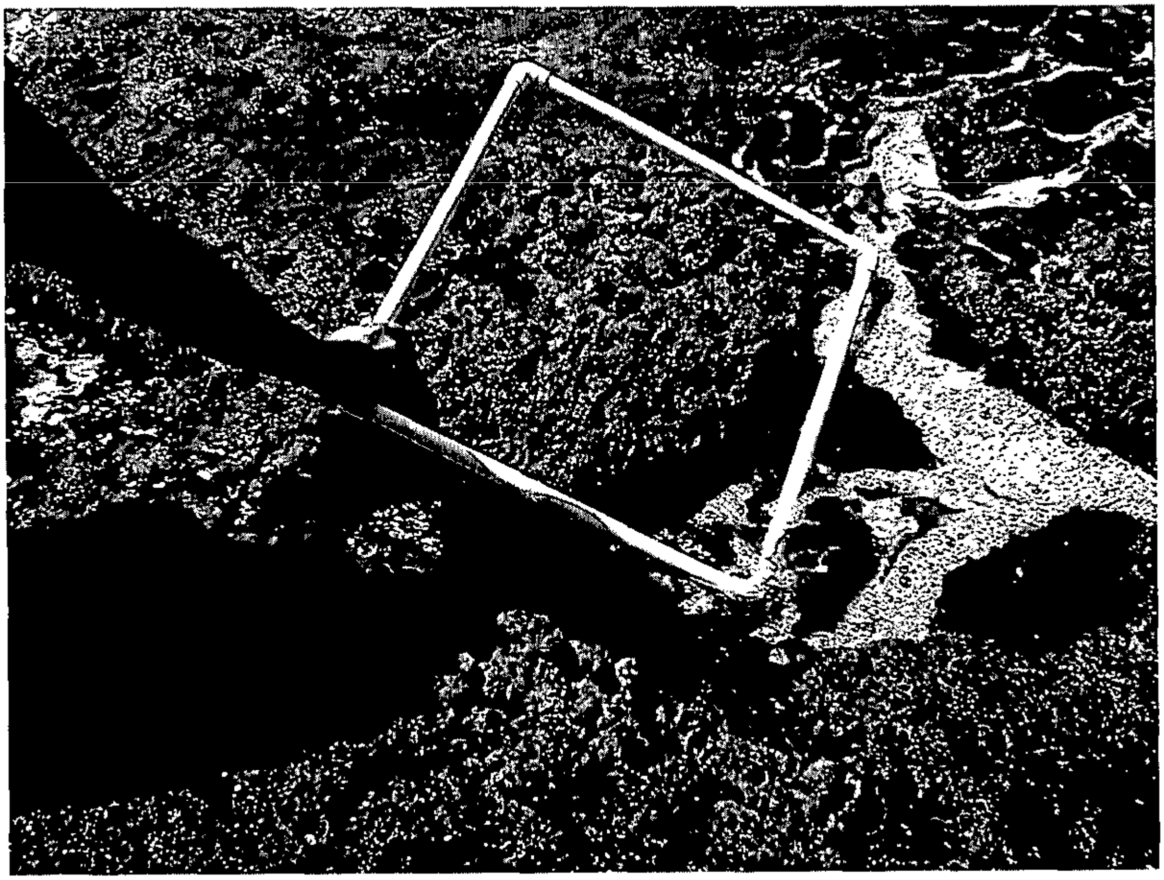


Figure 8. Georgia Avenue groin, 20 July 2001, 38° 49.938′ N, 75° 12.911′ W. Close photograph of rocks covered with sandbuilder worm colonies with 0.5 m x 0.5 m quadrat for scale.

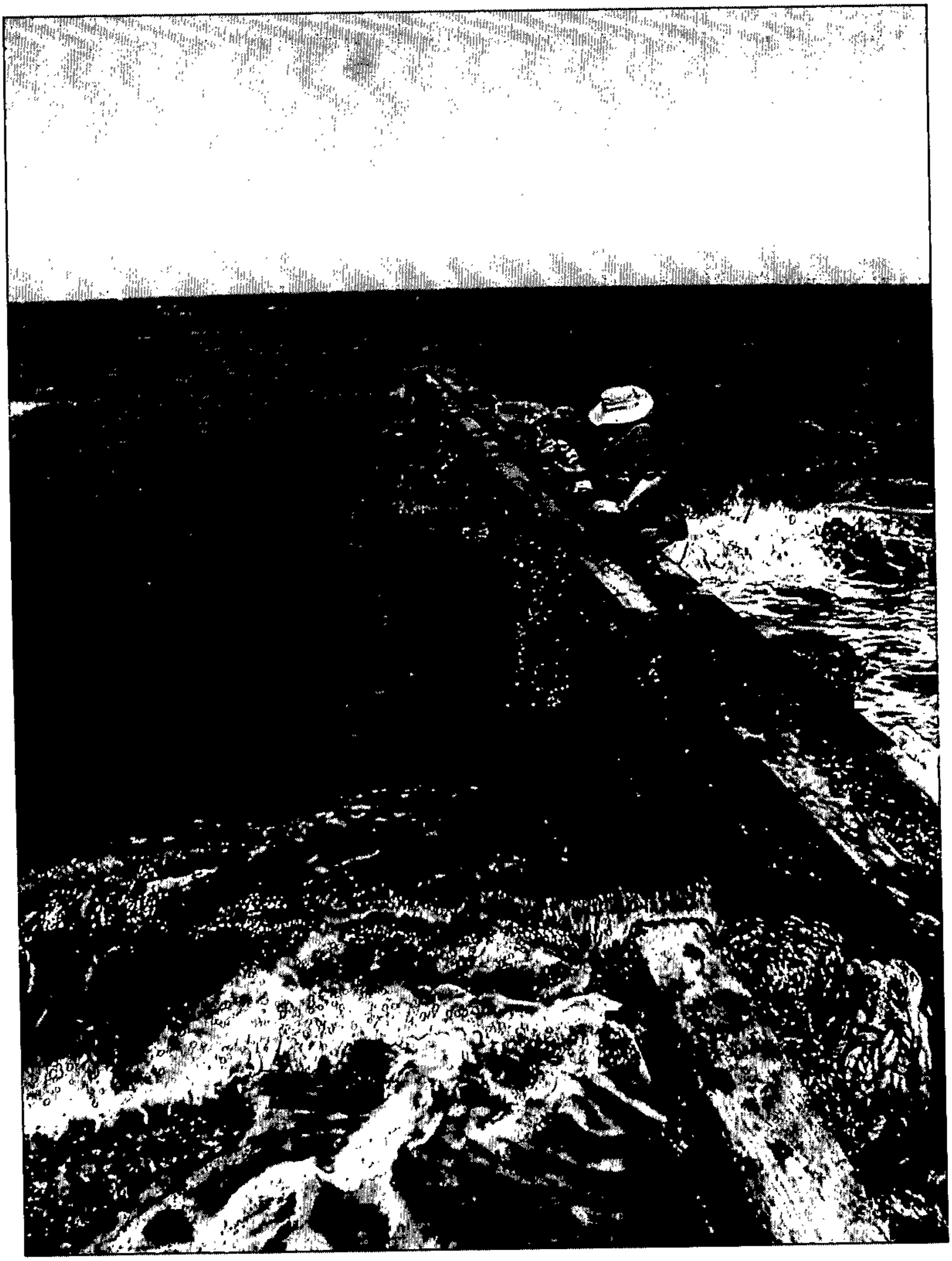


Figure 9. Wooden groin, 20 July 2001, 38° 49.876′ N, 75° 12.860′ W. No sandbuilder worm colonies observed.

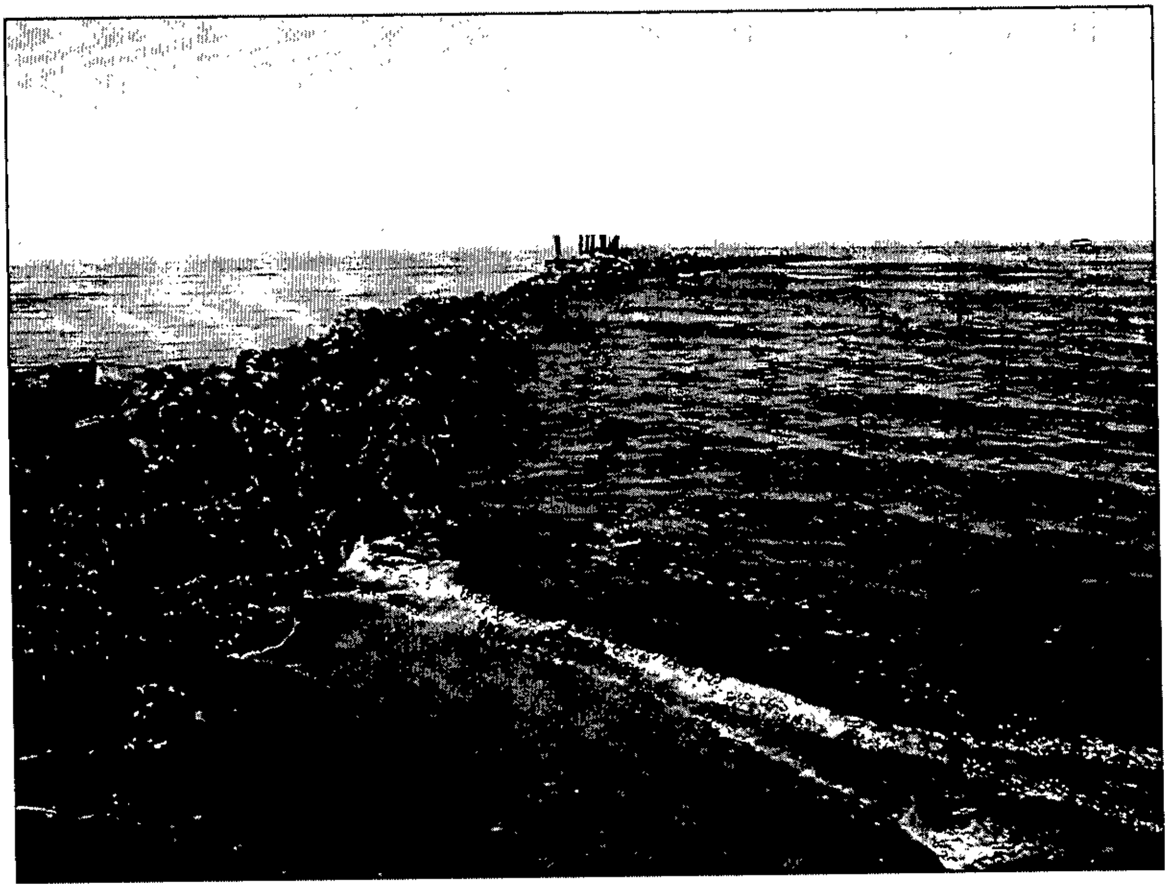


Figure 10. Old Inlet Jetty, 21 July 2001, 38° 48.743′ N, 75° 11.668′ W. Wide photograph showing full length of jetty.

Figure 11. Old Inlet Jetty, 21 July 2001, 38° 48.743′ N, 75° 11.668′ W. Wide photograph from mid-jetty towards shore.

Figure 12. Old Inlet Jetty, 21 July 2001, 38° 48.743′ N, 75° 11.668′ W. Close photograph showing sandbuilder reef with mussels and new tube growth.

Figure 13. Old Inlet Jetty, 21 July 2001, 38° 48.743′ N, 75° 11.668′ W. Close photograph showing sandbuilder worm colonies completely covering rocks and other debris.

Figure 14. Old Inlet Jetty, 21 July 2001, 38° 48.743′ N, 75° 11.668′ W. Wide photograph from mid-jetty towards bay showing sandbuilder reef on flanks of jetty structure.

Figure 15. Sand beach, 21 July 2001, 38° 49.150′ N, 75° 12.070′ W. No sandbuilder worm colonies observed at beach slope break.

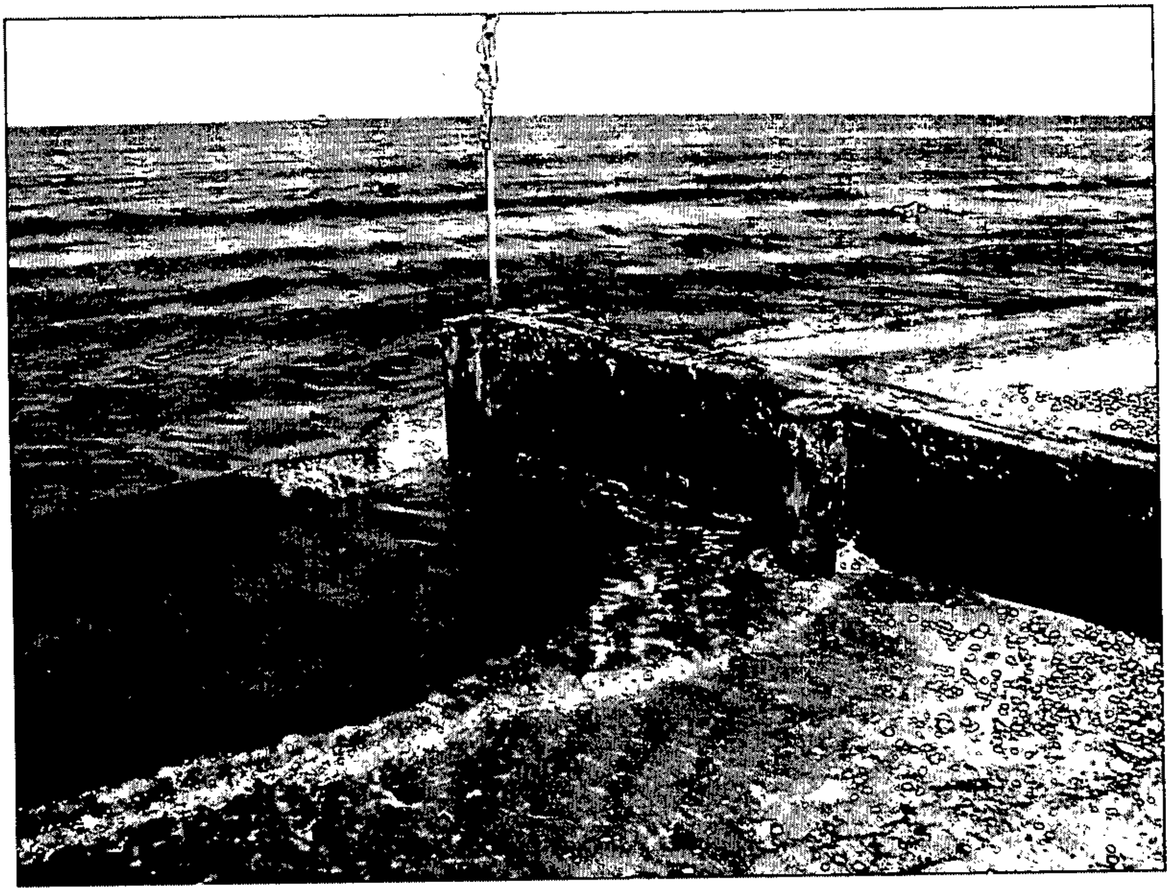


Figure 16. Wooden groin, 21 July 2001, 38° 49.646′ N, 75° 12.586′ W. No sandbuilder worm colonies observed.

TABLES

Table 1. Summary of locations and characterization of *Sabellaria* reefs at Broadkill Beach, surveyed 20-21 July 2001.

Sabellaria Reef	GPS Location	Dimensions	Reef Description	Figure #s
Alabama Avenue Groin	38° 49.997′ N 75° 12.966′ W	• Triangular reef at bayward end of groin • 6.3 m wide alongshore × 5 m visible bayward, starting 9 m from beach slope break • Plan area: 16 m^2	• Rock substratum, 50-100% covered • Reef settled with blue mussels and algae (sea lettuce and filamentous green) • New *Sabellaria* tube growth • Seawater: 25.3 °C, 22.2 ‰	• Location: Fig. 1 • Reef: Figs. 3, 4, 5
Georgia Avenue Groin	38° 49.938′ N 75° 12.911′ W	• Chevron-shaped reef at bayward end of groin • 5 m wide alongshore × 8 m visible bayward, plus band 27 m × 2 m wide, starting 4 m from beach slope break • Plan area: 74 m^2	• Rock substratum, edges of rocks to 100% covered • Reef settled with blue mussels and algae (sea lettuce and filamentous green), and false angel wing mollusc in burrows • Seawater: 25.5 °C, 25.2 ‰	• Location: Fig. 1 • Reef: Figs. 6, 7, 8
Old Inlet Jetty	38° 48.743′ N 75° 11.668′ W	• Long jetty • 3-4 m wide alongshore × 65 m (estimate) bayward, starting 2 – 5 m from beach slope break • Plan area: 228 m^2	• Coverage from 10% near beach to 100% at seaward end • Reef settled with mussels, porous, new tube growth • Seawater: 26.8 °C, 25.7 ‰	• Location: Fig. 2 • Reef: Figs. 10, 11, 12, 13, 14
Summary: three reefs in 3.0 km of beach		Of total area: 318 m^2	All on artificial rock	

Table 2. Summary of seawater temperature, salinity, beach slope and sediment grain size data Broadkill Beach, surveyed 20-21 July 2001.

Date, Local Time and Location	GPS Latitude and Longitude	Seawater Temperature, °C	Salinity, ‰	Beach Slope, °	Sediment Median Grain Size and Sorting Coefficient	Comments
20 July 13:51	38° 50.438′ N 75° 13.593′ W	26.6	24.4	6	582 µm coarse sand 0.21 ϕ sorting coefficient	Sandbar at north end Fig. 3
20 July 14:13	38° 50.239′ N 75° 13.304′ W	25.8	25.3	8	760 µm coarse sand 0.36 ϕ sorting coefficient	
20 July 14:29 Alabama Avenue	38° 49.997′ N 75° 12.966′ W	25.3	22.2	7	798 µm coarse sand 1.13 ϕ sorting coefficient	Sandbuilder reef Figs. 3-4
20 July 14:42 Georgia Avenue	38° 49.938′ N 75° 12.911′ W	25.2	25.2	6	648 µm coarse sand 0.63 ϕ sorting coefficient	Sandbuilder reef Figs. 6-8
20 July 15:08	38° 49.876′ N 75° 12.860′ W	25.3	25.5	8	225 µm fine sand 0.33 ϕ sorting coefficient	Wooden groin Fig. 9
21 July 14:14	38° 48.407′ N 75° 11.383′ W	26.6	26.5	6	196 µm fine sand 0.38 ϕ sorting coefficient	Student's transect site
21 July 14:31 Old Inlet Jetty	38° 48.743′ N 75° 11.668′ W	26.8	25.7	5	196 µm fine 0.24 ϕ sorting coefficient	Sandbuilder reef Figs. 10-14
21 July 15:18	38° 49.150′ N 75° 12.070′ W	28.0	26.4	5	900 µm coarse sand 0.11 ϕ sorting coefficient	Fig. 15
21 July 15:46	38° 49.646′ N 75° 12.586′ W	28.0	26.0	7	601 µm coarse sand 0.21 ϕ sorting coefficient	Fig.16
21 July 15: 54	38° 49.701′ N 75° 12.659′ W	Not determined	Not determined	Not determined	Not determined	Last wooden groin, no sandbuilder colonies
Summary	Ranges:	25.2 – 28.0 °C	22.2 – 26.5 ‰	5 – 8 °	Fine or coarse sands, well sorted to poorly sorted	

PRE-CONSTRUCTION SHOREBIRD STUDY

Delaware Bay Shorebird Studies, Spring 2001

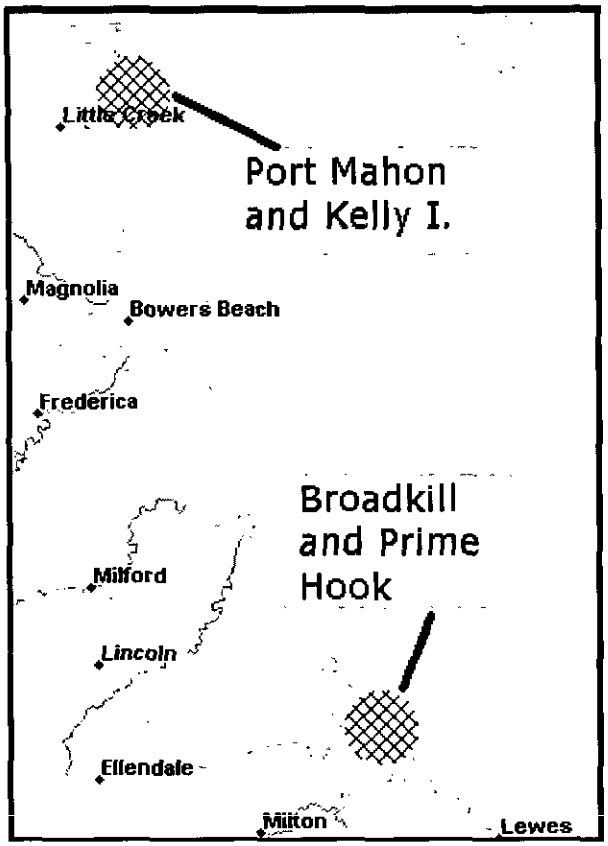
Prepared for the U.S. Army Corps of Engineers
By Brian A. Harrington and Sea McKeon
Manomet Center for Conservation Sciences
Manomet, MA 02345, December 2001

Exec. Summary

Introduction

Delaware Bay is recognized as one of the most critical stopovers worldwide for shorebirds migrating from their wintering grounds in Central and South America to their Arctic and Subarctic breeding grounds (WHSRN). Each spring shorebirds arrive by the hundreds of thousands on their staging grounds along the Delaware Bay to fuel up for the last leg of their northward journey. Their stopover coincides with the peak of horseshoe crab spawning. The millions of horseshoe crab eggs laid in the sand along bayshore beaches comprise an important food source for the migrants. Previous studies have called attention to apparent declines in the numbers of several shorebird species on their staging grounds (Howe et al. 1989, Clark et al. 1993, Harrington 1995) and point to the importance of habitat protection in the conservation of these species (Myers et al. 1987).

Figure 1. Location of study areas covered in this report.



The Army Corps of Engineers is proposing to use dredged material from deepening the Delaware River Federal Navigation Channel for shoreline restoration, including a restoration project at Kelly Island. Another project proposes sand placement at Broadkill beach.

Shoreline beaches on Delaware Bay are known to attract high numbers of shorebirds. In order to determine whether the shoreline restoration projects will benefit migratory shorebirds, it is necessary to collect and analyze quantitative and qualitative baseline data on shorebird use of the sites prior to construction. This report summarizes baseline work completed during May and June 2001. Principal emphasis was on documenting usage by shorebirds at the locations proposed for restoration, as well as at comparable abutting locations that are not slated for restoration. Rapid assessments also were made of common invertebrate animals in the same areas.

METHODS

A. Birds

Migratory shorebird surveys were conducted at four locations on the Delaware coast during May 2001 (Figure 1). Bird surveys were made with binoculars and a 20x telescope, and were conducted from vantage points that caused minimal disturbance to birds along the shoreline. Counting focused mostly on shoreline habitats, but flight-line counts of shorebirds moving between shoreline and nearby marshland habitats also were made near Port Mahon. Each shoreline section was divided into 25-31 subsections and marked. Counts were kept for each subsection. Species names, codes, and binomial names are shown in Appendix 4.

Knowing what tidal stage is best for counting shorebirds is important to designing sequel studies. Between two and eight shoreline surveys were made at each location each week. Shorebirds were counted at predicted mid-tide times (roughly half way between low and high tides) on each day that counts were made. A second count also was made either 3 hr before or 3 hr after the predicted mid-tide time, i.e. at approximately the time of predicted low or high tide. Correlation analysis was used to describe overall relationships between counts made at mid- versus low tide, and between counts made at mid- versus high tides. Analysis of Variance (SAS Institute 1999) was used to compare counts between the 4 study areas.

The methodology of the shoreline surveys closely followed that used by The Nature Conservancy and Manomet Center for Conservation Sciences for shorebird monitoring at Port Mahon in 1997 and 1999. The study areas (Appendix 1) are as follows:

1. Kelly Island (proposed for restoration): This area extends north along the shoreline from the mouth of the Mahon River for about 1.6 km to Deepwater Point.
2. Port Mahon: Surveyed as a future control site, the area is a 1 km stretch of shoreline just south of the mouth of the Mahon River where Port Mahon Road runs parallel to the Delaware Bay.
3. Broadkill Beach (proposed for restoration): The study area is a 4.4 km stretch of shoreline from Arizona Avenue south to the end of the paved road.
4. Prime Hook Beach: An equivalent area of habitat similar to Broadkill beach was surveyed as a future control site.

The study areas on Port Mahon and Broadkill beaches were divided into linear sections and marked. Similar linear segments were measured on

Kelly Island and Prime Hook Beach. Marker locations were also GPS-located for future reference (see Appendix 1).

To assess the levels of shorebird use of marshlands proximate to the study beaches, we counted birds moving between the marsh and the shore during peak migration weeks. These surveys were made near the north end of the Port Mahon study site for 10 minutes at dawn and/or dusk, times when shorebirds are expected to be moving to and from roosting sites.

B. Invertebrate animals.

At each of the 4 study locations (at the tideline in transect 1,10, 20, and 25), core samples were collected during visits to the study sites after May 15th. Samples were sorted with a standard 1 mm screen to identify macro-invertebrate taxa. Fifty-two samples were assessed. Cores were collected on site, screened in the field, and washed with salt water into suitable containers marked for date and location, refrigerated, and sorted within 36 hours.

Invertebrates were identified as follows:

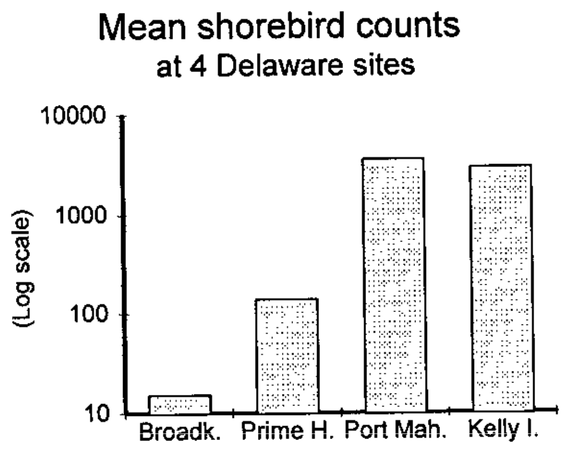
Gastropods and bivalves to genus (or better)
Amphipods and polychaete worms to family (or better)
Shrimps to genus (or better)
Crabs to genus (or better)
Insects and spiders to order (or better)
Scarce invertebrates (occurrence < 5% by head count) to class

Results

Part I. Bird studies.

A. Results, Overall shorebird counts

Figure 2. Mean counts of shorebirds at the four Delaware coastal study sites.

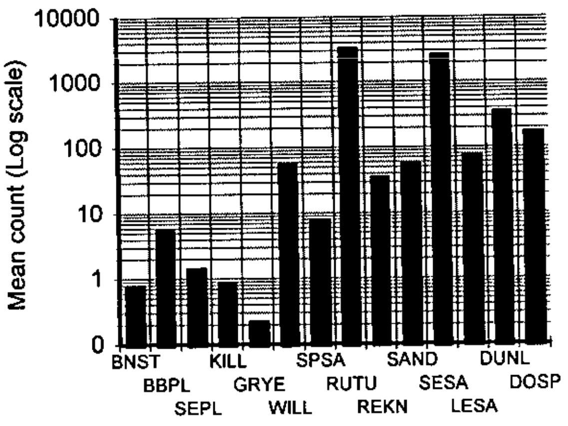


Counts of shorebirds were substantially and significantly ($P<0.001$) higher at the Port Mahon/Kelly Island pair of sites versus the Broadkill/Prime Hook pair of sites (Figure 2, note the log scale).

The overall numbers of shorebirds using the PAIRED study sites differed only slightly (and nonsignificantly) within the pair of locations near Port Mahon and within the pair near Prime Hook. Mean number of shorebirds counted at the Mahon pair was 3561 and 2965 versus 140 and 15 at the Prime Hook/Broadkill pair.

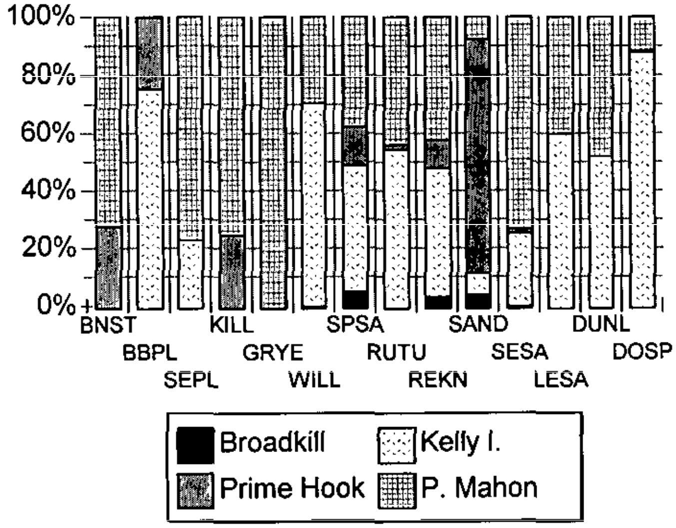
The relative abundance of the various species during the whole study is shown in Figure 3. As shown, two species (Ruddy Turnstone and Semipalmated Sandpiper) far outnumbered other species (88% of the grand mean); the two next most common species (Dunlin and dowitchers) comprised only 8% of the mean.

Figure 3. Relative abundance of shorebird taxa on 4 Delaware Bay beaches, Delaware, May 2001 (note log scale). See Appendix 4 for species codes and names).



Most species were found at the four study sites in numbers that were commensurate to the totals of all shorebirds counted at the sites, but a few stand out as having skewed occurrence (Figure 4).

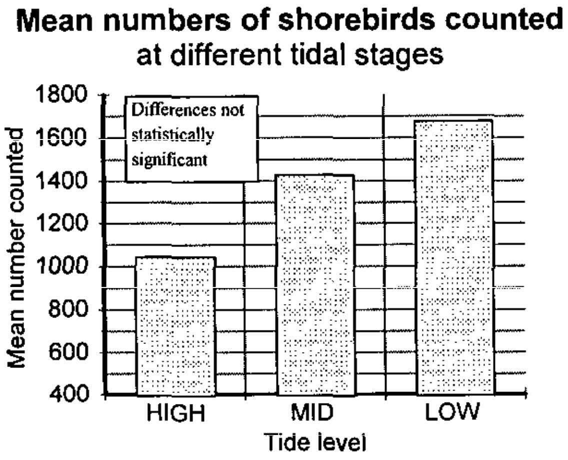
Figure 4. Relative occurrence of shorebird taxa at 4 Delaware Bay shore locations, Delaware, May 2001. See Appendix 4 for species names and codes.



For example, 70% of the Willets were found at Kelly Island (where slightly less than half of all shorebirds were counted). More than half of the Sanderlings were counted at Prime Hook, where only a small fraction of all shorebirds were counted. Most (>70%) of the Semipalmated Sandpipers were found at Port Mahon, whereas most of the Least Sandpipers (>60%) and dowitchers (> 88%) were at Kelly Island. In some other species, for example Killdeer or Black-bellied Plover, the percentages look skewed, but too few were found to make meaningful site comparisons. Finally, in only two species, Willet and Semipalmated Sandpiper, were the mean counts statistically significantly different (P <0.05) among the four locations.

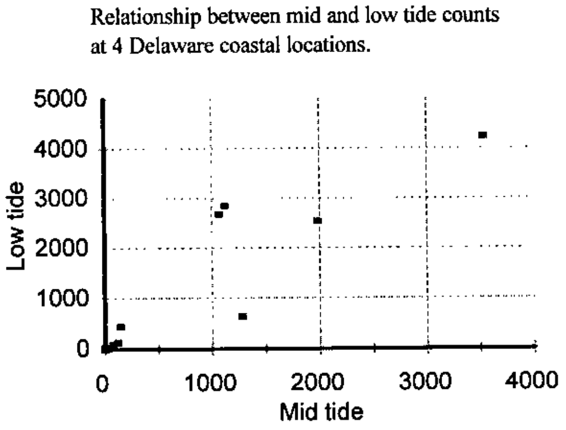
B. Results, counts in relation to tides.

Figure 5.



Numbers of shorebirds counted tended to be lower at high tides than at low tides (Figure 5), but the difference was significant only at Port Mahon; in aggregate there was no significant difference of mean counts made at low, mid, or high tide. However, given the large difference of numbers counted at the 3 locations we would not expect to find differences of the means of counts combined from all sites.

Figure 6. Correlation between mid- and low tide counts (r=0.91).

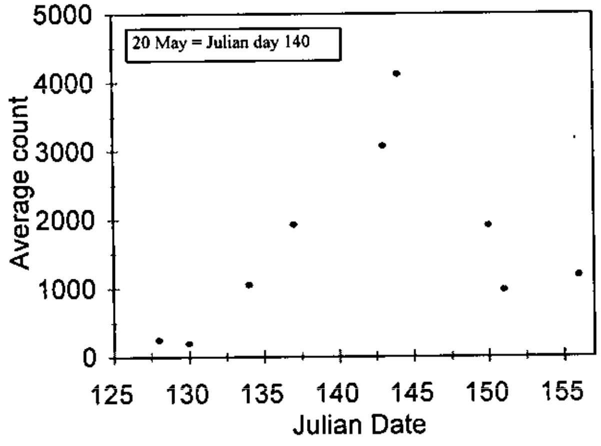

Relationship between mid and low tide counts at 4 Delaware coastal locations.

We found a close correlation between counts made at low tides versus mid-tides (Figure 6, r=0.91); the correlation between counts made at mid- and high tides was somewhat lower (r=0.77).

The overall results show the best time for counting is at lowest tides. The results also suggest that some shorebirds may use habitats away from the beaches during higher tidal phases.

C. Results, Migration chronology.

Figure 7. Mean combined counts of shorebirds by date at Port Mahon and Kelly Island.



The chronology of the 2001 Spring shorebird migration at the study sites (Figure 7) shows a noticeable build-up beginning between May 10th and 14th. Numbers evidently then increased steadily until May 25th before declining sharply sometime between then and May 30th.

Two species, Ruddy Turnstone and Semipalmated Sandpiper, predominated in these counts, and both showed an essentially similar pattern.

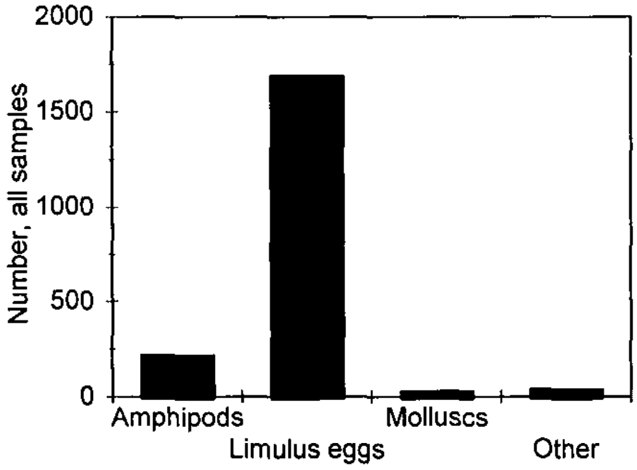
D. Flight-line counts. Dawn and dusk observations (detailed in Appendix 2) did not reveal any strong pattern of movement into and out of marshlands (Table 1). In part this was due to insufficient sampling effort. Most flying shorebirds were moving along the coast; the small numbers moving towards or away from the shoreline followed the course of the Mahon River.

Table 1. Dawn and dusk counts of shorebirds flying along the Delaware Bay shoreline and up/down the Mahon River, May 2001. See Appendix 4 for species names and codes

	RUTU	SESA	DOSP	Total
Dawn, upstream	27	0	42	69
Dawn, downstream	64	32	6	102
Dusk, upstream	51	6	14	71
Dusk, downstream	12	0	0	12
				254
Dawn, coast sw	322	260	0	582
Dawn, coast ne	643	1668	58	2369
Dusk, coast sw	262	1133	48	1443
Dusk, coast ne	188	122	2	312
				4706

Part II. Invertebrate results.

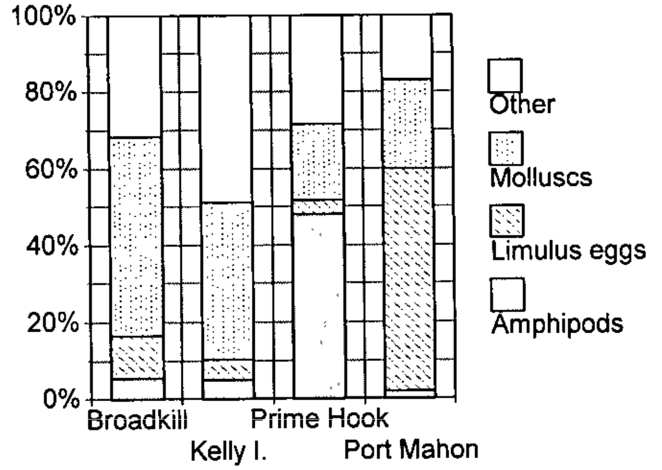
Figure 8. Relative counts of invertebrates in 4 Delaware Bay study areas, May 2001.



The most common "invertebrate" found in the sampling were horseshoe crab (*Limulus polyphemus*) eggs (Figure 8); the next most common invertebrates were amphipods, mostly of the genera *Gammarus* and *Haustorius*. Other forms of potential invertebrate shorebird food were relatively scarce.

Because the goal of the invertebrate sampling was to simply characterize the types present, any quantitative evaluation of the samples collected could well be inaccurate. However, crude comparisons of the percentages of each category found in the different study locations (Figure 9) suggest that there are differences in the invertebrate assemblage between the sites. This was especially evident for the most abundant item, the *Limulus* eggs.

Figure 9. Relative occurrence (based on mean counts) by four invertebrate categories in four Delaware Bay study sites, May 2001.



Discussion

This project was oriented to provide baseline information on shorebird use of two areas on the Delaware Bay shore, each one of which was subdivided into 2 sections, one of which is slated for restoration efforts and one of which is not. The premise underlying this design was that one of the sites in each pair would act as a 'control' in comparisons that would be made after restoration efforts were completed. A key question is whether our selection of 'subsites' was appropriate. We have evaluated our information with respect to bird numbers, relative species abundance, and in a very limited way (not adequately quantified), invertebrate animal presence.

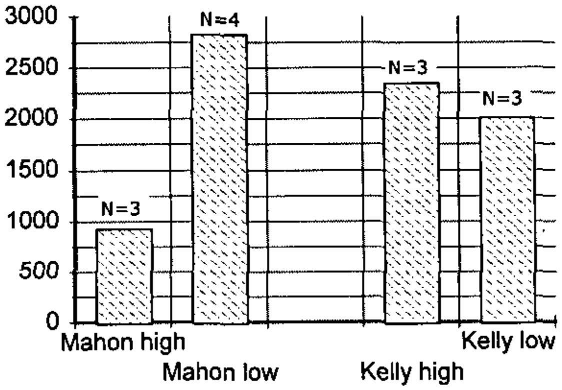
It is important to stress that our counts do not necessarily represent other Delaware Bay shoreline beaches or other habitats such as impoundments behind the beaches. We have included a single graph in Appendix 3 to reinforce this statement; it shows dramatically different species composition in impoundment versus beachfront habitats from some brief survey work completed in 1997. It also shows very different species ratios on beachfront habitats than we found in the 2 areas studied in May 2001. Although we cannot evaluate the causes underlying these differences, we believe that they are derived from differences in the ways that shorebirds are using different habitats (eg mudflats of impoundments versus sandy beaches) and from differences of the food resources in those habitats.

We believe that the bird counts from May/June 2001 provide a good basis for describing the numbers of shorebirds using the 4 shoreline sections. The counts at the southern (Broadkill/Prime Hook) location were similar to each other, and the northern counts (Port Mahon/Kelly Island) were similar to each other. In contrast, the northern pair of sites had much higher counts than the southern pair.

The level of invertebrate sampling that we were able to collect was insufficient to reliably quantify differences of the invertebrate animal populations between the sites, but it is clear that horseshoe crab eggs were far and away the most available food item, and that they were far more abundant at Port Mahon than at the other three locations.

Figure 10

Mean shorebird counts at high and low tides at Port Mahon and Kelly Island



Field time also was inadequate for documenting activities of shorebirds, including prey selection, while they were being counted, but it was clear that for most species Kelly Island was used principally as a roosting site whereas the other three areas were used primarily as foraging sites. If Kelly I wwas used principally for roosting, we would expect greater numbers of shorebirds to have been counted there at times when foraging habitats were restricted or inaccessible, i.e. during high tides. We have only limited samples for evaluating this, and they show the expected pattern (Figure 10); however, the differences are not statistically significant, perhaps due to the small sample sizes.

Ideally the pairs of sites we selected for this work would have been identical with respect to bird numbers, species composition, activity budgets of the birds, and accessibility of prey populations. This, of course, was not the case (Table 2). Perhaps the most important disparity was the difference of foraging activities between the Port Mahon and the Kelly Island sites. It remains to be seen whether this difference will be maintained after restoration work is completed at the Kelly Island site, i.e. whether it will continue to be principally used by shorebirds as a roosting site or whether

Table 2. Estimated similarity of key habitat components within two pairs of Delaware Bay *shoreline habitats (see Appendix one for location information).*

	Comparable bird numbers?	Comparable bird foraging activities	Comparable invertebrates	Similar substrates	Comparable human activity
Port Mahon/Kelly Island	yes	*no*	*no*	*no*	no
Prime Hook/Broadkill	yes	yes	marginally ?	yes	no

alterations to it will make it an attractive foraging site. Another consideration is human activity at the sites. As shown (Table 2), human activities were not comparable between the paired sites at both the northern and the southern locations. At the northern location the 'control' site (Port Mahon) is substantially more accessible to human activities than at the restoration site (Kelly Island). This did not appear to be a major issue in 2001 with respect to numbers of birds counted. However, human activities may have contributed to the lower counts at the Broadkill versus Prime Hook locations, but we had insufficient data to analyze for this.

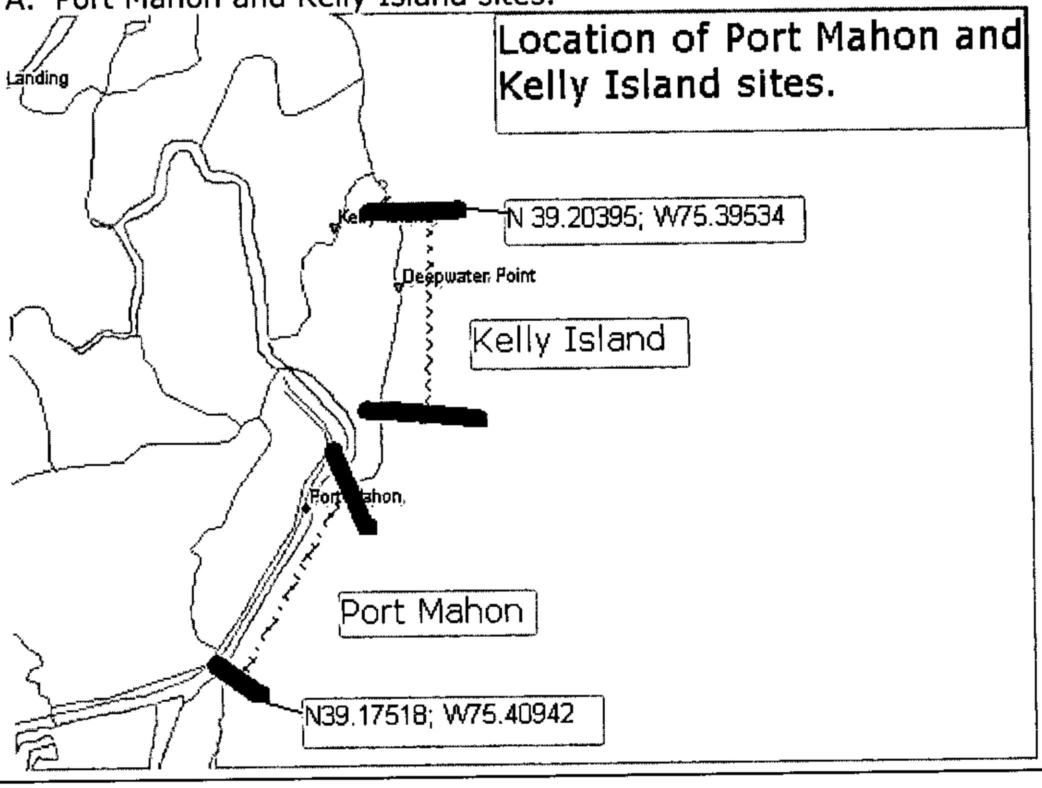
Recommendations.

Based on our work in 2001, we believe that work in later phases of this project can be improved by:

- Increased design and time given to the invertebrate sampling, including observations from locations heavily used by shorebirds but not necessarily appropriate as study sites for comparing effects of restoration activities, for example foraging habitats at the mouth of the Mispilllion River. (Goal would be to better understand characteristics of heavily used locations to improved restoration design) [work would require an additional, full-time field hand]
- Collection of data on shorebird foraging rates and success rates [would require an additional half-time field hand]
- Collection of data on numbers of birds foraging/not foraging during each count series (relatively small increased time requirement)
- Collection of data on shorebird prey preferences [work would need to commence 3 weeks prior to major shorebird arrival period, and continue through mid-June, and would require an additional half-time field hand].

Appendix 1. Locations of four Delaware study sites evaluated for shorebird usage, May 2001.

A. Port Mahon and Kelly Island sites.



B. Broadkill and Prime Hook sites.

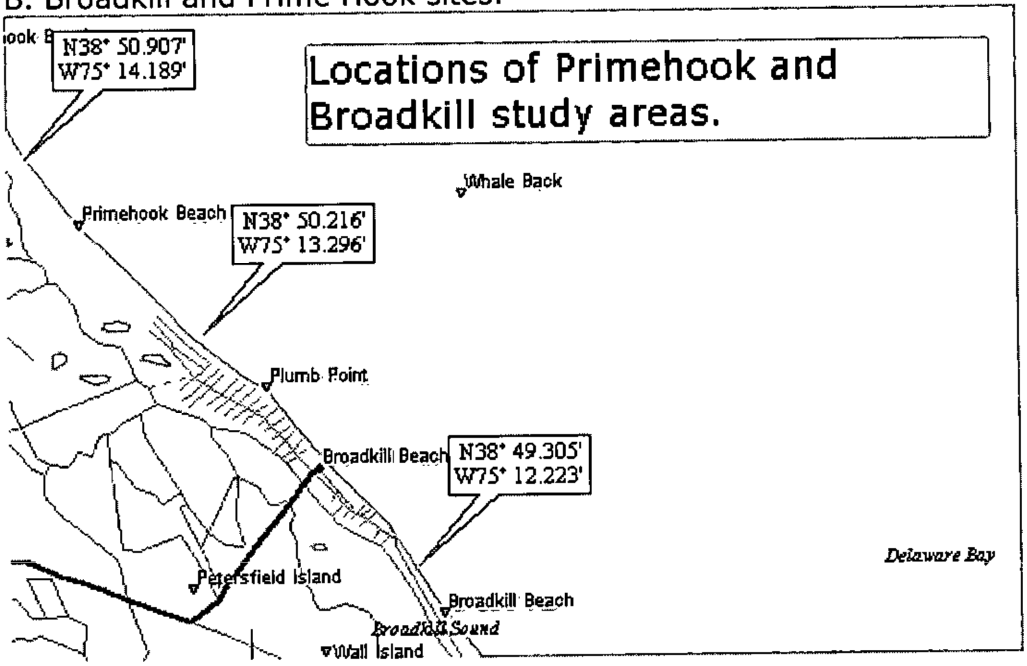


Table A1. Locations of transect markers.

Port Mahon Rd.

	Deg. north	Deg. west	min North	Min West
1	39.17518	75.40942	10.51	24.57
2	39.17559	75.40884	10.54	24.53
3	39.17596	75.40832	10.56	24.50
4	39.17638	75.40790	10.58	24.47
5	39.17689	75.40753	10.61	24.45
6	39.17720	75.40726	10.63	24.44
7	39.17766	75.40691	10.66	24.41
8	39.17814	75.40654	10.69	24.39
9	39.17859	75.40614	10.72	24.37
10	39.17905	75.40577	10.74	24.35
11	39.17952	75.40539	10.77	24.32
12	39.17999	75.40502	10.80	24.30
13	39.18044	75.40464	10.83	24.28
14	39.18091	75.40426	10.85	24.26
15	39.18137	75.40389	10.88	24.23
16	39.18185	75.40349	10.91	24.21
17	39.18231	75.40314	10.94	24.19
18	39.18278	75.40275	10.97	24.16
19	39.18324	75.40238	10.99	24.14
20	39.18370	75.40203	11.02	24.12
21	39.18419	75.40176	11.05	24.11
22	39.18472	75.40157	11.08	24.09
23	39.18525	75.40139	11.12	24.08
24	39.18578	75.40121	11.15	24.07
25	39.18630	75.40096	11.18	24.06
26	39.18679	75.40064	11.21	24.04
27	39.18725	75.40028	11.23	24.02
28	39.18772	75.39990	11.26	23.99
29	39.18818	75.39952	11.29	23.97
30	39.18866	75.39917	11.32	23.95
31	39.18913	75.39884	11.35	23.93

Kelly Island

	Deg. north	Deg. west		
1	39.19164	75.39620	11.50	23.77
2	39.19219	75.39637	11.53	23.78
3	39.19271	75.39634	11.56	23.78
4	39.19323	75.39627	11.59	23.78
5	39.19377	75.39606	11.63	23.76
6	39.19432	75.39601	11.66	23.76
7	39.19480	75.39606	11.69	23.76
8	39.19533	75.39606	11.72	23.76
9	39.19585	75.39594	11.75	23.76
10	39.19641	75.39609	11.78	23.77
11	39.19694	75.39630	11.82	23.78
12	39.19737	75.39670	11.84	23.80
13	39.19793	75.39686	11.88	23.81
14	39.19848	75.39687	11.91	23.81
15	39.19902	75.39681	11.94	23.81
16	39.19956	75.39681	11.97	23.81
17	39.20010	75.39673	12.01	23.80
18	39.20062	75.39670	12.04	23.80
19	39.20119	75.39651	12.07	23.79
20	39.20161	75.39643	12.10	23.79
21	39.20192	75.39635	12.12	23.78
22	39.20243	75.39613	12.15	23.77
23	39.20304	75.39533	12.18	23.72
24	39.20363	75.39525	12.22	23.72
25	39.20395	75.39534	12.24	23.72

Broadkill

1	38.82174	75.20362	49.3044	12.22
2	38.88217	75.20407	52.9302	12.24
3	38.82277	75.20464	49.3662	12.28
4	38.82318	75.20497	49.3908	12.30
5	38.82370	75.20551	49.422	12.33
6	38.82414	75.20606	49.4484	12.36
7	38.82455	75.20663	49.473	12.40
8	38.82492	75.20708	49.4952	12.42
9	38.82543	75.20763	49.5258	12.46
10	38.82589	75.20811	49.5534	12.49
11	38.82647	75.20879	49.5882	12.53
12	38.82701	75.20944	49.6206	12.57
13	38.82741	75.20991	49.6446	12.59
14	38.82790	75.21063	49.674	12.64
15	38.82861	75.21156	49.7166	12.69
16	38.82930	75.21231	49.758	12.74
17	38.83013	75.21342	49.8078	12.81
18	38.83070	75.21387	49.842	12.83
19	38.83116	75.21440	49.8696	12.86
20	38.83167	75.21499	49.9002	12.90
21	38.83215	75.21544	49.929	12.93
22	38.83265	75.21595	49.959	12.96
23	38.83314	75.21638	49.9884	12.98
24	38.83359	75.21705	50.0154	13.02
25	38.83404	75.21756	50.0424	13.05
26	38.83450	75.21811	50.07	13.09
27	38.83503	75.21877	50.1018	13.13
28	38.83549	75.21946	50.1294	13.17
29	38.83590	75.22009	50.154	13.21
30	38.83647	75.22090	50.1882	13.25
31	38.83690	75.22147	50.214	13.29

Prime Hook

1	38.83778	75.22286	50.2668	13.37
2	38.83827	75.22367	50.2962	13.42
3	38.83882	75.22470	50.3292	13.48
4	38.83928	75.22527	50.3568	13.52
5	38.83990	75.22606	50.394	13.56
6	38.84023	75.22656	50.4138	13.59
7	38.84054	75.22693	50.4324	13.62
8	38.84095	75.22743	50.457	13.65
9	38.84132	75.22801	50.4792	13.68
10	38.84165	75.22843	50.499	13.71
11	38.84211	75.22922	50.5266	13.75
12	38.84251	75.22977	50.5506	13.79
13	38.84310	75.23040	50.586	13.82
14	38.84355	75.23094	50.613	13.86
15	38.84400	75.23162	50.64	13.90
16	38.84457	75.23223	50.6742	13.93
17	38.84496	75.23265	50.6976	13.96
18	38.84551	75.23336	50.7306	14.00
19	38.84606	75.23398	50.7636	14.04
20	38.84623	75.23472	50.7738	14.08
21	38.84659	75.23455	50.7954	14.07
22	38.84701	75.23502	50.8206	14.10
23	38.84751	75.23547	50.8506	14.13
24	38.84797	75.23590	50.8782	14.15
25	38.84851	75.23642	50.9106	14.19

Appendix 2. Dawn and dusk counts of shorebirds moving along the Delaware Bay shoreline at Port Mahon, and counts of shorebirds moving up and down the Mahon River, May 2001. (Species codes are shown in Appendix XX).

8 May. The dusk survey along Port Mahon Rd. had 3 large flocks of RUTU moving north along the coastline, and some 45 SBDO moving upstream along the Mahon River (northwest).

14 May, Kelly Island. The 10 minute mud flat survey yielded very little: 4 LESA at mid-tide and a flock of 30 DUNL at high tide.

17 May, Port Mahon. The 10-min marsh scan revealed 4 GRYE, 6 SBDO, 130+ DUNL

23 May, Port Mahon marsh scan, 10 min. Flying sw along shoreline, 70 SESA, 42 RUTU, 17 SBDO, 13 DUNL. Courtship flights, 4 WILL.

Dusk scan. RUTU: 214 se along shore
72 nw along shore
12 downstream along Mahon R.
38 Upstream along Mahon R.

SBDO: 48 se along shoreline
2 nw along shore
14 upstream along Mahon R.

SESA: 320+ se along shoreline
54 nw along shoreline

24 May, Dawn scan. RUTU: 322 se along coast
64 downstream along Mahon R.
SESA: 1025 nw along shore (apparently from impoundment)
14 se along coast
SBDO 32 downstream along Mahon R.
9 NW from impoundments
BBPL 6 flying high NE, from inland.

30 May, Dawn scan. RUTU: 643 moving N along coast
27 nw along Mahon R.
SBDO: 49 N. along coast
43 nw up Mahon R.
SESA: 1341 N. along coast
246 S. along coast
6 downstream along Mahon R.

Mid-day scan: GRYE: 6 nw along shore

WILL: 4 displaying

31 May, Dusk.

RUTU: 48 sw along coast
24 ne along coast
13 upstream along Mahon R.

SESA 542 sw along coast
6 upstream along Mahon R.

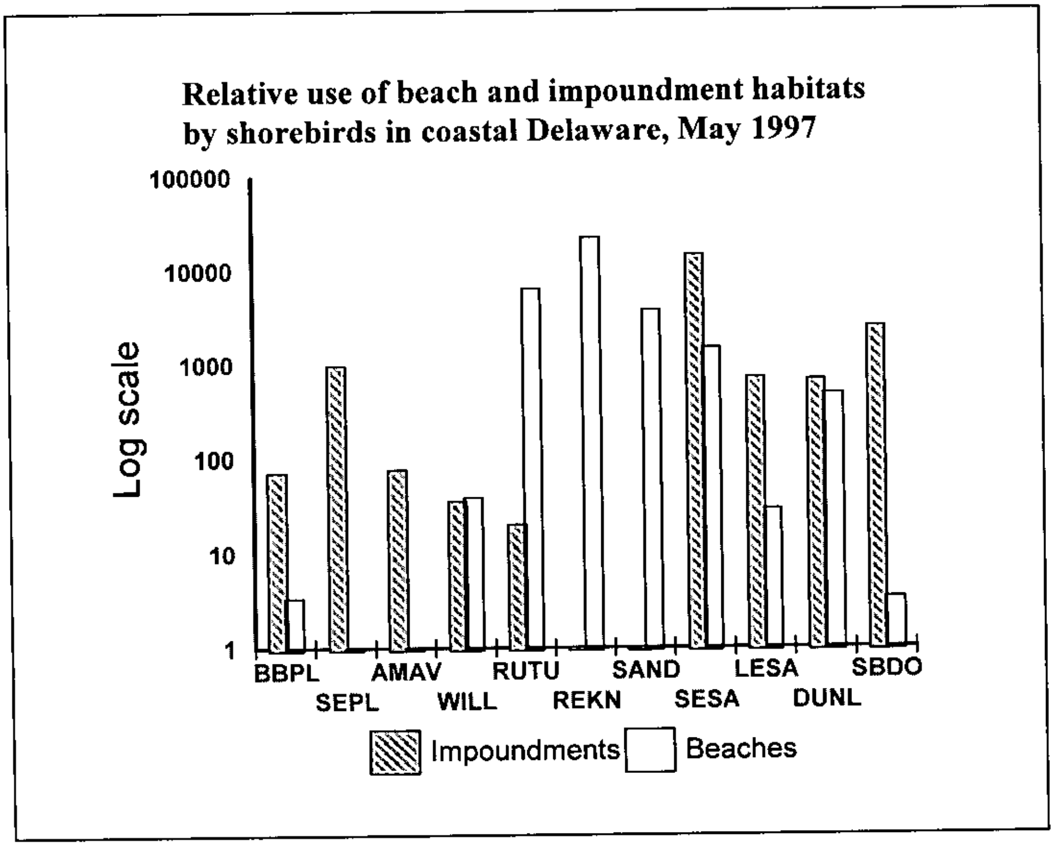
5 June, 10-min Marsh scan

WILL: 6 displaying
SBDO: 6 flying north

Dusk Survey

SESA: 271 sw along coast
68 ne along coast
RUTU: 104 ne along coast

Appendix 3.


Relative use of beach and impoundment habitats
by shorebirds in coastal Delaware, May 1997
Log scale
100000
10000
1000
100
10
1
BBPL
SEPL
AMAV
WILL
RUTU
REKN
SAND
SESA
LESA
DUNL
SBDO
▨ Impoundments
☐ Beaches

Appendix 4. Species codes, common and binomial names used in this report.

Code	Common name	Binomial name
BBPL	Black-bellied Plover	*Pluvialus squatarola*
PIPL	Piping Plover	*Charadrius melodus*
SEPL	Semipalmated Plover	*C. semipalmatus*
KILL	Killdeer	*C. vociferus*
BNST	Black-necked Stilt	*Himantopus mexicanus*
GRYE	Greater Yellowlegs	*Totanus melanoleuca*
LEYE	Lesser Yellowlegs	*T. flavipes*
WILL	Willet	*Catoptrophorus semipalmatus*
SPSA	Spotted Sandpiper	*Actitis macularia*
RUTU	Ruddy Turnstone	*Arenaria interpres*
REKN	Red Knot	*Calidris canutus*
SAND	Sanderling	*C. alba*
SESA	Semipalmated Sandpiper	*C. pusilla*
LESA	Least Sandpiper	*C. munitilla*
DUNL	Dunlin	*C. alpina*
DOSP	Dowitcher spp.[a]	*Limnodromus* spp.

[a] All or almost all were Short-billed Dowitchers

TURTLE MONITORING SCOPE OF WORK

SCOPE OF WORK

TURTLE OBSERVATION ABOARD HOPPER DREDGES

1.0 PROJECT: Monitoring for sea turtles aboard a hopper dredge for the Salem River maintenance dredging in Salem, New Jersey.

2.0 GENERAL: Under Section 7 of the Endangered Species Act of 1977 (16 U.S.C. 1531 et seq.) the National Marine Fisheries Service is now requiring whale and sea turtle monitoring for all hopper dredging activities conducted during June though mid November within the Philadelphia Corps of Engineers jurisdiction. The observer will work closely with the dredge crew to identify and record dredging incidents with sea turtles and other endangered species. Sampling for turtle and turtle parts will be accomplished through observation and inspection of the hopper along with screening of the intake structure or hopper overflow.

Endangered species are those whose prospects for survival are in immediate danger because of a loss or change of habitat, over-exploitation, predation, competition or disease. Threatened species are those that may become endangered if conditions surrounding the species begin or continue to deteriorate. Species may be classified on a Federal or State basis.

There are six species of endangered whales that have been observed along the Atlantic coast, and occasionally within the Delaware Bay. These include the sperm whale (*Physeter catodon*), fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliae*), blue Whale (*Balaenoptera musculus*), sei whale (*Balaenoptera borealis*) and black right whale (*Balaena glacialis*). These are migratory animals that travel north and south along the Atlantic coast.

There are five species of threatened or endangered sea turtles that occasionally enter the project area. These include the endangered Kemp's ridley turtle (*Lepidochelys kempii*), leatherback turtle (*Dermochelys coriacea*), and hawksbill turtle (*Eretmochelys imbricata*), and the threatened green turtle (*Chelonia mydas*) and loggerhead turtle (*Caretta caretta*). With the exception of the loggerhead these species breed further south from Florida through the Caribbean and the Gulf of Mexico. The loggerhead may have historically nested along the coastal barrier beaches. No known nesting sites are within the project area.

3.0 PURPOSE: This Scope of Work (SOW) outlines the Contractor's requirements for conducting sea turtle monitoring for maintenance dredging in the Salem River. The Contractor will supply an endangered species observer(s) to be placed aboard the dredging plant to monitor for the presence of sea turtles. The Contractor must demonstrate previous experience in endangered species monitoring. Observers must be certified in writing as acceptable by NMFS for endangered species observing and handling.

4.0 DETAILED REQUIREMENTS: The Contractor shall complete the following tasks:

4.1 SITE DESCRIPTION/BACKGROUND: The observer will stay on board the hopper dredge and conduct monitoring of the baskets or screening over either the inflow or overflow for sea turtles.

4.2 ENDANGERED SPECIES PROTECTION: The Contractor shall provide education materials to dredge personnel on sea turtles, and whales, as well as instruct the dredge operator in the proper procedures used for documenting any whale sightings (the dredge operator is responsible for recording the presence of any whales within or around the project site). The contractor shall advise dredge personnel that there are civil and criminal penalties for harming, harassing, or killing sea turtles and whales that are protected under the Endangered Species Act and the Marine Mammal Protection Act.

4.3 GENERAL PROVISIONS OF OBSERVER WATCH: One observer is to be placed on board the dredge to provide observation coverage approximately 50 percent of the total dredging time. Observers will check for the presence of any sea turtles or fragments of sea turtles entrained with the dredged materials brought on board the dredge or seen in the vicinity of the vessel. The dredge operator will provide acceptable devices to screen inflow discharge water. Screens will remain in place and functional while the observer is on board the dredge. The dredge crew will assist the observer as needed to maintain the screening devices in working order. This may include assistance in emptying the specimen collecting baskets of clay and other accumulated debris at the end of each cut. Time will be made available for cleaning and examining the baskets.

4.4 OBSERVATION PERIOD: The sea turtle observer shall be on board the dredge during all dredging operation. While on board the dredge the observer shall provide the required inspection coverage on a rotating, six (6) hours on and six (6) hours off, basis. In addition, these rotating six (6) hour periods should vary from week to week. The Contractor will provide the above coverage for approximately 60 days.

4.5 DISPOSITION OF TURTLE PARTS: All specimens of sea turtles or their parts collected during the observation period will be described in detail and photographed. Any dead sea turtles or sea turtle parts shall be placed in plastic bags labeled to note location and time taken, and placed in a freezer (freezer space will be provided by the dredge operator). All sea turtle and sea turtle parts stored in the freezer will be collected by a Corps of Engineers representative and stored until such time as it is picked up or delivered to the National Marine Fisheries Service - Northeast Region (NMFS). In the event of an injured turtle, the Marine Mammal Stranding Center in Brigantine should be contacted (609-266-0538). Unless otherwise directed by the Stranding Center, injured turtles will be held on board the dredge until such time as the trained observer decides that the turtle is ready for release or should be transported to the National Aquarium in Baltimore for rehabilitation.

4.6 REPORTING: The Contractor will follow the reporting procedures listed below:

4.6.1. A sample observation sheet is appended to the end of this section and shall be used to record each observation. A sheet shall be completed for every cycle (load), whether sea turtles are present or not. The observation sheets will be submitted on a biweekly basis to the Contracting Officer's Representative. All data in the original form shall be forwarded directly to Beth Brandreth, Environmental Resources Branch, Wanamaker Building, 100 Penn Square East, Philadelphia, PA 19107-3390, within 10 days of collection, and copies of the data will be supplied to the Contracting Officer's Representative and NMFS. Following completion of the project, a copy of the Contractor's log regarding sea turtles shall be forwarded to Beth Brandreth.

4.6.2 Continuous liaison with Beth Brandreth, Environmental Resources Branch, Philadelphia District Office shall be maintained to avoid problems with execution of this contract and to assure compliance with prescribed Corps of Engineers' policies and procedures. It will be the responsibility of the Contractor to report all significant developments.

4.6.3 A summary report of observation shall be submitted to both Mr. Doug Beach of NMFS and the Corps of Engineers (COE) within 7 days of the completion of the contract period.

4.6.4 Any collisions with a whale or sea turtle or sighting of any injured or incapacitated whale or sea turtle will be reported immediately to the Corps of Engineers. The order of contact within the Corps of Engineers will be as follows:

Order of Contact of Corps Personnel for Observer to Report
Endangered Species Death or Injury (Including Those Not

Directly Related To the Dredging Activities)

Title	Telephone Number Work Hours	After Hours
Corps, Inspector	*	*
Beth Brandreth, Environmental Resources Branch	(215) 656-6558	(609) 435-4435

* Phone numbers will be provided upon initiation of work

5.0 GOVERNMENT-FURNISHED MATERIALS: The following materials will be furnished to the Contractor:

5.1 Observation sheets will be supplied by the Contracting Officer's Representative (Corps).

5.2 While on board, meals and sleeping quarter with a bathroom and a shower facility will be provided by the dredge operator.

5.3 Boat transportation will be provided by the dredge operator between the dredge and the mainland. Observers will strive to cooperate with existing crewboat schedules while maintaining minimum requirements of the observer contract.

5.4 The dredge operator will provide the observer with a statement of dangers associated with work on board the dredge. The observer will follow these safety requirements and recommendations while on board the dredge and while in transit between the dredge and the mainland.

5.5 Corps of Engineers Manual, EM 385-1-1, dated April 1981, entitled "General Safety Requirements" will be provided.

6.0 PERIOD OF PERFORMANCE: The Contractor shall report to the dredge on or around August 2, 2000 as indicated in paragraph 4.1. The work is expected to be completed approximately 60 days after the notice to proceed. Total time for performance of this work shall not exceed November 15, 2000.

TURTLE OBSERVATION REPORTING LOG

PROJECT: **Salem River Maintenance Dredging, 2000**.

TURTLE OBSERVER NOTES

LOAD NUMBER__________ DATE____________ TIME

LOCATION IN CHANNEL: LATITUDE___________________ LONGITUDE

WEATHER CONDITIONS

PORT BASKET CONTENTS

TURTLE OR TURTLE PARTS PRESENT YES_____________ NO

COMMENTS AND OTHER OBSERVATIONS

BRIDGE WATCH: TIME_________________ LOCATION

NUMBER OF TURTLES SIGHTED

_______________________________________ OBSERVER'S NAME

_______________________________________DATE

_____DAILY WHALE REPORTING LOG

PROJECT: **Salem River Maintenance Dredging, 2000**.

2. WHALE SIGHTED: YES _____ NO

3. TYPE OF WHALE:

4. TIME:

5. NUMBER OF WHALES SIGHTED:
ADULT ________ JUVENILE

6. NUMBER OF WHALE INJURED:
ADULT _______ JUVENILE _______ WORK RELATED: YES_______ NO

7. NUMBER OF WHALES KILLED:
ADULT _______ JUVENILE _______ WORK RELATED: YES_______ NO

8. LOCATION:

9. REMARKS:

10. SIGNATURE:

11. TITLE:
PROJECT: SALEM RIVER MAINTENANCE DREDGING 2000, INCIDENT REPORT OF SEA TURTLE MORTALITY AND DREDGING ACTIVITIES

Species ____
Date ______________________________ Time 24 hour clock
Geographic site
Location: Latitude ________________________ Longitude
Vessel name
Type of dredging activity
Load #
Sampling method
Location specimen recovered
Draghead deflector? YES_____________ NO
Condition of Deflector
Weather conditions
Water temp: Surface _____________ Column
Head width
Plastron Length
Carapace S.L. Length
Carapace S.L. width

Carapace O.C. Length
Carapace O.C. width
Condition of specimen
Turtle tagged YES______________ NO
Tag # __________________ Tag Date
Comments/other

Observer's Name

ADULT AND JUVENILE HORSESHOE CRAB DATA

Methods of Adult Horseshoe Crab Spawning Survey

Survey methods in the spring of 2001 for adult spawning horseshoe crabs followed those of instituted by the Delaware National Estuarine Research Reserve. Horseshoe crabs were counted along two transects (South and North) for each Delaware Bay beach. Transects were 50-m in length and followed the "crab-line" or limit of the beach where crabs are most intensely laying. Crabs were counted and identified as to sex 1-m above and below the "crab-line." Logistically, two surveyors worked each transect with one counting males and the other females each using a mechanical count recorders. The timing of each survey commenced at 20-minutes following the evening high tide for the new (22 May) or full moon (5 June).

Results of Adult Horseshoe Crab Spawning Survey

Spawning adult horseshoe crabs were more abundant at the Port Mahon Beach than at Kelly Island. At the peak spawning date, coinciding with the full moon of 5 June, there were roughly twice as many crabs along the Port Mahon beach. The reported count for this transect was initiated about a hour after the optimal start time. Counts along the Kelly Island shoreline were remarkably similar between the north and south transects at 618 and 600, respectively. The shoreline habitat of Kelly Island at the time of spawning was a mix of the higher salt marsh hummock with eroding cuts in between. Spawning crabs occupied positions in any suitable substrate where the females could dig in. Ratios of sexes were always very similar at about 2 to 3 males to each female. The spawning habitat of the Port Mahon beach was much more favorable with a wide swath of uninterrupted sandy beach. The area of the North Transect had many more obstructions in the lower intertidal zone and may account for the lower numbers at that beach. Port Mahon beach was also surveyed on an earlier date of lesser spawning activity that coincided with the new moon of 22 May. Counts from this survey were approximately half those of the full moon survey. At that time, a survey of the Kelly Island shoreline was precluded by severe thunderstorms in the area; Kelly Island is only reachable by boat.

Counts of horseshoe crabs at Kelly Island and Port Mahon during the 2001 spawning survey

Beach	Date	South Transect		North Transect	
		Male	**Female**	**Male**	**Female**
Kelly Island	22 May	Thunderstorm precluded beach survey			
Port Mahon		431	154	115	50
Kelly Island	5 June	400	200	399	219
Port Mahon		989	403	487*	161*

* Counts reported are from a second pass of the beach; on the initial pass, the mechanical counter for males malfunctioned. The count for females on the initial pass was 281.

Juvenile Horseshoe Crab Survey

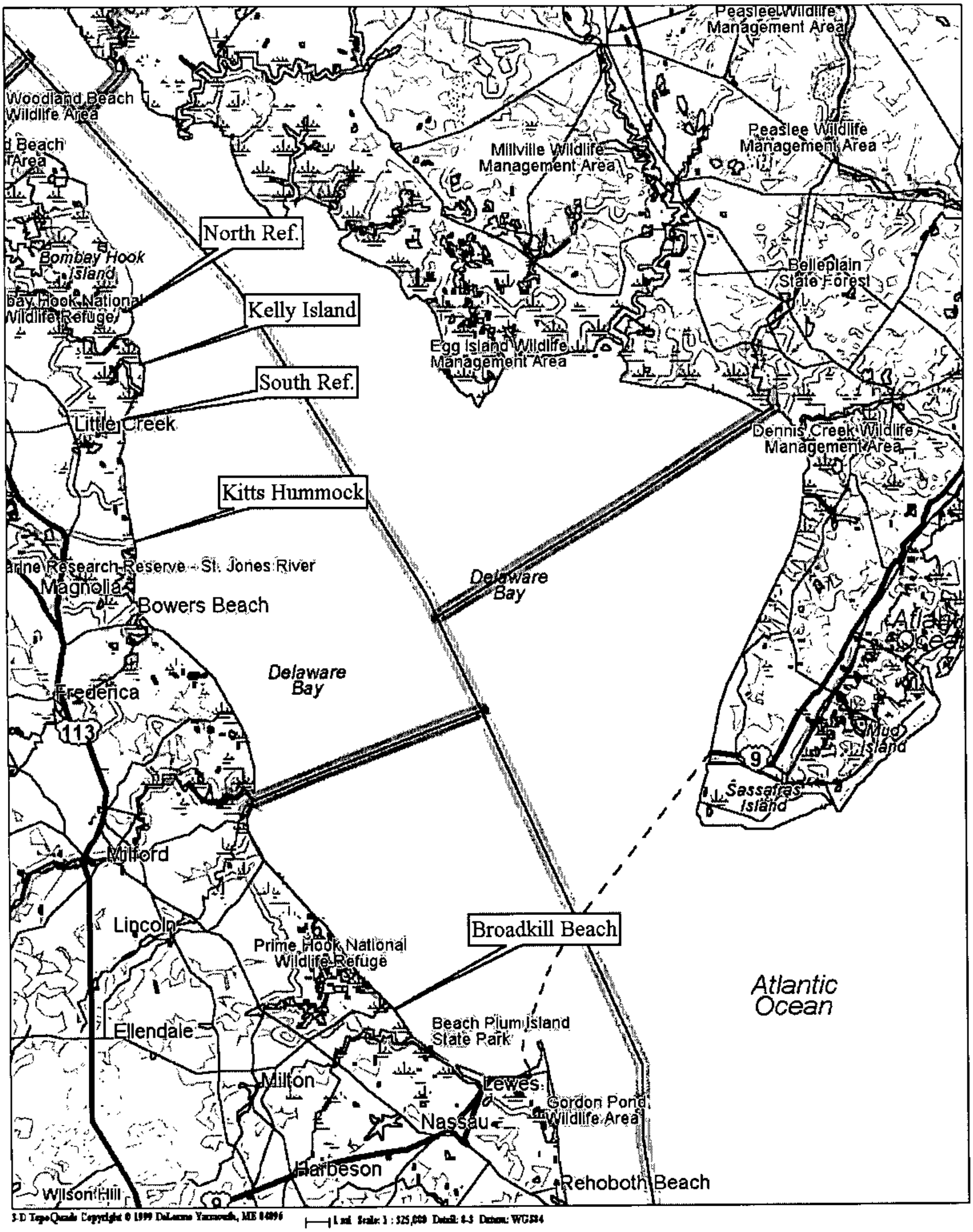
A juvenile horseshoe crab survey was conducted along Delaware Bay shoreline during September 2001. The survey was designed to characterize juvenile crab use of subtidal habitats adjacent to known spawning beaches. Beaches surveyed included Kelly Island, Kitts Hummock, Broadkill, and in addition adjacent reference areas located 0.5-miles north and south of Kelly Island. The south reference beach was near the Port Mahon spawning beach. Two transects were surveyed at each beach. Each transect constituted replicate tows (8 total) of a biological dredge at distances from the mean high tide line of 50, 100, 200, and 300-ft. The dredge was towed for a distance of 30-ft as measured by an incremental tag line. The biological dredge was constructed with a rectangular framed mouth of 10 x 18-in fitted with ¼-in mesh nylon bag. In operation, the heavy flat bar of the frame scraped along the bottom and dislodged epibenthic fauna into the collection bag. Following a tow, bottom material collected by the dredge was washed, sieved, and sorted; all juvenile horseshoe crabs were counted and measured for carapace width.

Results of *Juvenile Horseshoe Crab Survey*

Juvenile horseshoe crabs were collected at only one of the five beaches surveyed. A total of 11 crabs were collected at the south reference area approximately 0.5-miles downbay from Kelly Island. This area is also immediately downbay of the Port Mahon spawning beach. Crabs were collected in low numbers in each tow. The highest number was 3 from the second replicate tow at the 100-ft distance. Crabs were only collected at distances of 100 to 300-ft from the mean high water mark. Sizes of juvenile crabs measured as carapace width ranged from 6 to 14-mm.

Summary of juvenile horseshoe crab survey of Delaware Bay Beaches conducted during September, 2001

Beach	**Transect**	**50-ft**	**100-ft**	**200-ft**	**300-ft**	**Total**
Kelly Island	1	0/0	0/0	0/0	0/0	0
	2	0/0	0/0	0/0	0/0	0
Reference North	3	0/0	0/0	0/0	0/0	0
	4	0/0	0/0	0/0	0/0	0
Reference South	5	0/0	**0/1**	**1/0**	**2/0**	**4**
	6	0/0	**0/3**	**0/2**	**2/0**	**7**
Kitts Hummock	7	0/0	0/0	0/0	0/0	0
	8	0/0	0/0	0/0	0/0	0
Broadkill Beach	9	0/0	0/0	0/0	0/0	0
	10	0/0	0/0	0/0	0/0	0



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