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Summary Biomonitoring Report
for
Site 8 - Nitroglycerin Plant Office
Indian Head Division
Naval Surface Warfare Center
Indian Head, Maryland

Engineering Field Activity Chesapeake
Naval Facilities Engineering Command
Northern Division Contract Number N62472-90-D-1298
Contract Task Order 0117

03-95-25

SUMMARY BIOMONITORING REPORT
FOR
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
Engineering Field Activity Chesapeake
Environmental Branch Code 18
Naval Facilities Engineering Command
Washington Navy Yard, Building 212
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EXECUTIVE SUMMARY

Site 8 - Nitroglycerin Plant Office (Site 8) is an Installation Restoration (IR) Site located at the Indian Head Division, Naval Surface Warfare Center in Indian Head, Maryland. Site 8 contained elevated levels of mercury that were recently excavated and removed during a removal action that was completed in October 1994. Halliburton NUS has performed ten quarterly rounds of biomonitoring at the Site 8 Pond/marsh from October 1992 through January 1995. The primary objective of the work was to assess the impact of elevated levels of mercury on the biota of Site 8. Biomonitoring at Site 8 included sampling and analysis of periphyton, benthic macroinvertebrates, and fish. Work was performed at the Site 8 pond/marsh and two control sites.

The periphyton community of Site 8 has varied significantly during the last 2½ years. However, periphyton, which are short-lived and very prolific, often show in these kinds of seasonal shifts in community structure.

The Site 8 benthic macroinvertebrate community is composed largely of herbivores that feed on attached algae (e.g., chironomids) and detritivores that feed on organic detritus (e.g., olgochaetes). There has been very little change in benthic community structure since April 1993. The simple structure and low diversity of the Site 8 benthic community are typical of tidal freshwater marshes and ponds of the east coast.

Although mercury levels in sediments of the Site 8 pond are higher than those at the control sites, there does not appear to be a corresponding increase in mercury levels detected in fish and other aquatic organisms at Site 8. Evidence indicates that mercury levels in Site 8 biota are generally low, and that birds and mammals that feed on fish and invertebrates are not at risk from elevated levels of mercury. Concentrations of mercury in fish tissue from Site 8 over the course of this biomonitoring have revealed no clear differences between species (with the exception of *Gambusia*, which appear to accumulate mercury to a certain extent) or areas (between Site 8 and the two control sites).

Lead sampling and analysis was added to the biomonitoring program in July 1994. Composite samples of fish from the Site 8 pond contained low concentrations of lead in July and October 1994, as did samples of fish from the two control sites. However, this data has shown no evidence that lead from the Site 8 sediments has moved into the food chain to a significant degree.

1.0 INTRODUCTION

The Northern Division of the Naval Facilities Engineering Command issued Contract Task Order Number 0117 (CTO 117) to Halliburton NUS Corporation (Halliburton NUS) in 1993 under Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract No. N62472-90-D-1298. CTO 117 is for eight rounds of quarterly biomonitoring at the Navy Installation Restoration Program (IRP) Site 8 Nitroglycerin Plant Office (Site 8), at the Indian Head Division, Naval Surface Warfare Center (NSWC) in Indian Head, Maryland. NSWC is part of the Engineering Field Activity, Chesapeake (EFA Chesapeake), of the Naval Facilities Engineering Command. Under CTO 117, Halliburton NUS performed quarterly biomonitoring from April 1993 to January 1995. The initial objective of the Biomonitoring Program was to assess the impact of mercury contamination in the biota of Site 8 and evaluate the potential ecological impacts of a removal action at Site 8. The removal action at Site 8 consisted of excavating and removing sediment and soil with elevated mercury levels from the upper section of the Site 8 stream. (Design work for the removal action was performed by Halliburton NUS under CTO 099; removal action activities at Site 8 were essentially complete in October 1994.)

Under a previous CTO (CTO 064), Halliburton NUS developed a Biomonitoring Program for Site 8 that was presented to EFA Chesapeake in a site-specific Biomonitoring Plan (Halliburton NUS, 1992a). The plan outlined procedures for conducting quarterly biomonitoring at Site 8 through two distinct phases: Phases I and II. The program was designed so that it could be modified (particularly during Phase I) to achieve the overall objective of the biomonitoring program. Phase I was performed under CTO 064. During Phase I, which consisted of preliminary [U.S. Fish and Wildlife Service (USFWS)] sampling in July 1992 and two quarterly sampling events (October 1992 and January 1993), sample collection and analytical techniques were established and subsequently modified to better suit actual site conditions. Based on the results of Phase I, a revised (Revision 1) Biomonitoring Plan was prepared and issued in April 1993 (Halliburton NUS, 1993a). Phase II of the Biomonitoring Program, which was initiated in April 1993, has been performed under CTO 117. Phase II was completed with the January 1995 round of biomonitoring.

During implementation of the biomonitoring program, a potential source of lead contamination was identified at Site 8, and elevated lead levels were detected in the lower section of the Site 8 stream and marsh/pond area. As a result, the biomonitoring program was expanded to obtain information to assess the impact of lead at Site 8. Beginning with the April 1994 round of biomonitoring, fish and turtle samples from Site 8 were analyzed for lead as well as mercury, and the results of lead analyses were included in subsequent quarterly biomonitoring reports.

This report presents the results of the January 1995 biomonitoring, which was performed in accordance with the approved Biomonitoring Plan (Revision 1), and summarizes the results of biomonitoring since 1992. Except for the supplemental lead sampling and analyses, there have been no substantive changes in the biomonitoring program during Phase II. There have been minor changes in sampling procedures and analytical methods dictated by changes in environmental variables (e.g., water levels, water quality, abundance of a particular plant or animal species) and practical considerations.

1.1 BACKGROUND

For approximately 20 years, mercury was inadvertently released in small amounts from sink and floor drains in Building 766 of the Site 8 Nitroglycerin Plant Office. The Building 766 sink and floor drains emptied into a storm drain system that discharged into a small (unnamed) stream that flows south and east for approximately 1/4 mile, enters a cattail marsh and pond, then empties into Mattawoman Creek. Previous investigations determined that sediments and surface waters of the stream, marsh, and pond contained elevated concentrations of mercury (ABB-ES, 1992a; 1992b). The actual quantity of mercury that was released is unknown; however, it has been estimated that between 200 and 500 pounds of mercury were released to the environment at Site 8 (ABB-ES, 1992a).

In August 1992, Halliburton NUS began investigating the extent of mercury contamination in the soils, sediment, and surface water of Site 8 in accordance with an approved Abbreviated Field Sampling Plan (Halliburton NUS, 1992b). Mercury concentrations in sediments and soils in the upper stream section (near Building 766) ranged from non-detectable (lower than detection limits) to 671 mg/kg (Halliburton NUS, 1993b). Sediments in the marsh and pond had mercury concentrations ranging from non-detectable to 13.8 mg/kg. Background mercury concentrations (i.e., mercury levels in sediment and soil samples from the general vicinity of Site 8 but outside of the impacted stream corridor) ranged from non-detectable to 0.34 mg/kg (Halliburton NUS, 1993b).

The biomonitoring program developed by Halliburton NUS was designed to be carried out only in the marsh/pond area of Site 8. Because the velocity of the stream is reduced as it widens and flows into the marsh and pond, the pond is a natural sediment trap, holding silt, detritus, and organic matter from upstream. Unlike the stream, which is subject to extreme fluctuations in temperature, flow, and turbidity, the marsh and pond support an abundant growth of aquatic vegetation as well as a variety of planktonic organisms, aquatic insects, fish, reptiles, amphibians, wading birds, and waterfowl (personal observation, P. R. Moore - Halliburton NUS). The potential for contaminant exposure and bioaccumulation was considered to be higher in the marsh and pond than in the stream, and the biomonitoring effort concentrated on this area.

1.2 SITE DESCRIPTION

The study site (Site 8 marsh/pond) lies within the main (or northern) NSWC area. The Site 8 marsh/pond discharges into Mattawoman Creek via a 6-foot-diameter culvert running under Noble Road. In addition, two control sites have been identified and incorporated into the biomonitoring program. Control Site 1 is a beaver pond on the Stump Neck Annex of NSWC, approximately 3 miles southeast of Site 8 and 1/2 mile northwest of Alexandria Church. Control Site 1 was designated a control site in October 1992. Control Site 2 is in Mattawoman Creek, approximately 3 miles east of the NSWC, just upstream of the Maryland Highway 225 bridge. It was added prior to the January 1993 sampling round. The locations of Site 8 and Control Site 1 are shown on Figure 1-1.

Control Site 1 (Stump Neck beaver pond) is located on an unnamed tributary of the Chicamuxen Creek, the drainage to the south of Mattawoman Creek. This beaver pond was chosen as a control site because it offers security (access to the area is restricted and controlled by NSWC) and reasonably approximates the Site 8 pond in terms of water chemistry, water level, topography, and resident plants and animals. Control Site 2 (Mattawoman Creek) was selected because it appeared to offer better fish habitat than the beaver pond control site, and lies in the same drainage basin as the Site 8 stream and pond. Both Mattawoman Creek and Chicamuxen Creek are tributaries of the Potomac River.

Because Control Site 1 is approximately 2 miles upstream from Chicamuxen Creek and approximately 3 miles upstream from the Potomac River, it has not been contaminated by mercury from Site 8. Any pollutants (e.g., mercury) in its water, sediments, and biota are presumed to be from atmospheric or geologic sources rather than from Site 8.

Until the summer of 1992, the Site 8 pond was approximately 4 feet deep at its deepest point, the water level being maintained by a beaver dam lying just upstream of the culvert that drains the marsh/pond. The beaver dam was removed in the summer of 1992 and normal pool was lowered approximately 3 feet. During the October 1992 and January 1993 rounds of biomonitoring, the water level in the Site 8 pond was generally 1 to 2 feet deep. A weir was installed just upstream of the Noble Road culvert in April 1993, raising the water level in the pond by approximately 1 foot. Thus, permanent pool elevation will be intermediate between the high (pre-summer 1992) level maintained by the beaver dam and the extreme low level that existed in fall 1992 and winter 1993 after removal of the beaver dam.

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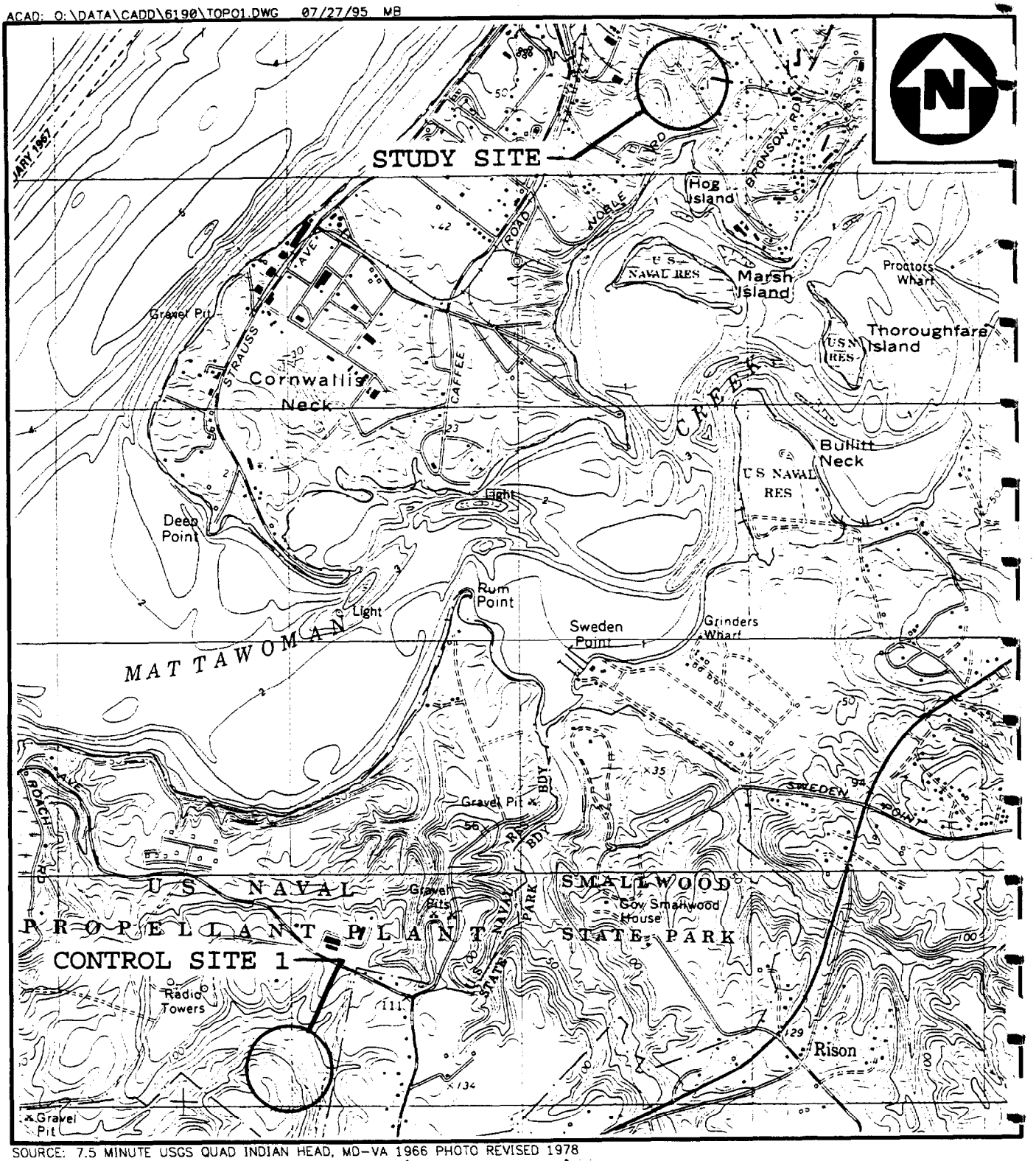

SOURCE: 7.5 MINUTE USGS QUAD INDIAN HEAD, MD-VA 1966 PHOTO REVISED 1978

LOCATION MAP - SITE 8 (STUDY SITE)
AND CONTROL SITE 1
BIOMONITORING PROGRAM
INSTALLATION RESTORATION PROGRAM, SITE 8
NITROGLYCERIN PLANT OFFICE

FIGURE 1-

0 2000 4000
SCALE IN FEET

Halliburton NUS CORPORATION

1.3 OBJECTIVES

The primary objective of the biomonitoring program was to assess the impact of mercury contamination on the biota of the Site 8 marsh/pond. Biomonitoring results were also to be used to evaluate potential environmental impacts of the removal action. Because the removal action was just recently completed, evaluation of potential impacts (if any) of the removal action is not practical. However based on the biomonitoring results to date, measurable impacts of the removal action are not expected to be significant in the next few years. Over a longer time period the removal action will have a positive impact on the site because a potential contamination source area has been eliminated. The October 1992 and January 1993 rounds of biomonitoring were intended to establish baseline conditions at Site 8 and provide information to refine and improve methods in subsequent phases of biomonitoring. The April 1993 round of biomonitoring was significant because it marked the first time that sampling was conducted in the Site 8 pond under normal (full-pool) conditions. The water level in the Site 8 pond has remained at full pool since July 1993. Barring unforeseen problems with the Noble Road dam and weir, the water level in the pond should remain relatively stable in the future, and biological communities should, in time, reach an equilibrium. In 1994, the objectives of the biomonitoring program expanded to include the assessment of possible lead contamination at Site 8. All fish and turtles collected in April and October of 1994 were analyzed for lead as well as mercury residues in tissue. Supplemental samples of Site 8 sediments were also obtained in May 1994, in an effort to better define the extent of lead contamination in the sediments of the Site 8 pond.

2.0 BIOMONITORING SAMPLING LOCATIONS AND METHODS

The January (winter) 1995 round of biomonitoring was conducted on February 2 and 3, 1995. Coastal Environmental Services, Inc. (Coastal), a subcontractor to Halliburton NUS, performed field sampling at six transects in the main area of the Site 8 marsh/pond (Transects 1, 2, 3, 4, 5, and 7) and at a location on the north side of Atkins Road Extension (Transect 10). The sampling locations are shown on Figure 2-1 (see full-size drawing pocket). Sampling was also performed at the two control sites.

The following ecological components were sampled and evaluated for the February 1995 round of biomonitoring:

- Surface water
- Periphyton
- Benthic Macroinvertebrates

2.1 WATER QUALITY MEASUREMENTS

Water temperature, dissolved oxygen (DO), pH, and conductivity measurements were taken in the field with a Hydrolab Surveyor II at a single, mid-water-column depth at the Site 8 pond and the two control sites. Salinity was measured in the field with a portable Yellow Springs Instruments (YSI) Salinity-Conductivity-Temperature meter. Grab samples of water were taken at the surface for total hardness and total organic carbon (TOC) and shipped to the Pittsburgh laboratory of Halliburton NUS for analysis.

2.2 PERIPHYTON SAMPLING

Periphyton was sampled with an artificial substrate, similar to that described in Standard Methods for the Examination of Water and Wastewater (APHA, 1989). This sampler consists of 8 glass slides in a frame supported by styrofoam floats. Two sets of periphyton samplers (a total of 16 slides) were placed at Transects 1-4 of Site 8 and the two control sites. After 14 days, the samplers were retrieved and transported to the laboratory for analysis.

Three randomly-selected slides from each 16-slide array were analyzed to determine ash-free dry weight, three were analyzed to determine chlorophyll-a content, and three were examined for species composition and abundance. One slide from each periphyton sampler was preserved and archived, in the event that

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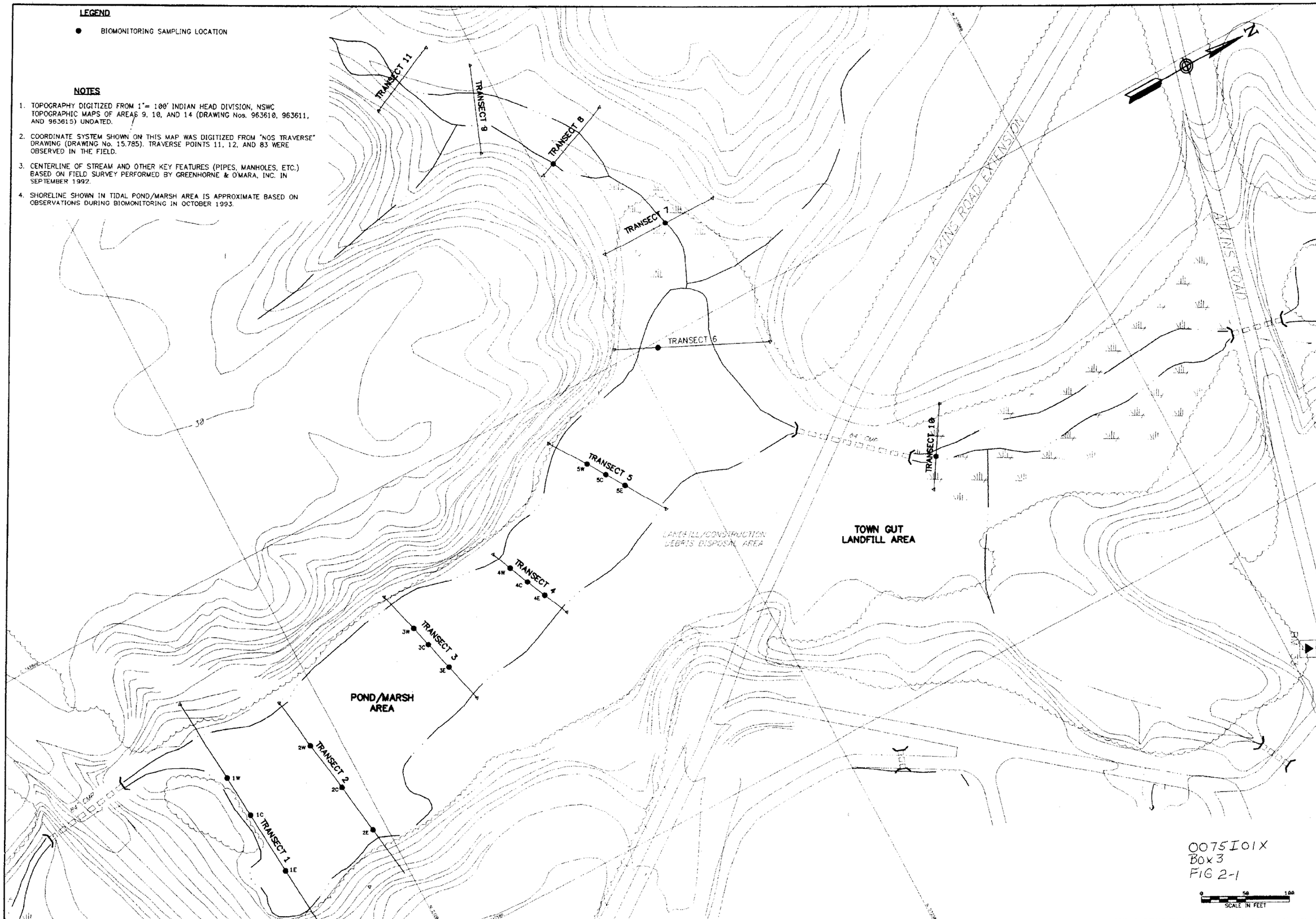
● BIOMONITORING SAMPLING LOCATION

NOTES

1. TOPOGRAPHY DIGITIZED FROM 1"= 100' INDIAN HEAD DIVISION, NSWC TOPOGRAPHIC MAPS OF AREAS 9, 10, AND 14 (DRAWING Nos. 963610, 963611, AND 963615) UNDATED.
2. COORDINATE SYSTEM SHOWN ON THIS MAP WAS DIGITIZED FROM "NOS TRAVERSE" DRAWING (DRAWING No. 15.785). TRAVERSE POINTS 11, 12, AND 83 WERE OBSERVED IN THE FIELD.
3. CENTERLINE OF STREAM AND OTHER KEY FEATURES (PIPES, MANHOLES, ETC.) BASED ON FIELD SURVEY PERFORMED BY GREENHORNE & O'MARA, INC. IN SEPTEMBER 1992.
4. SHORELINE SHOWN IN TIDAL POND/MARSH AREA IS APPROXIMATE BASED ON OBSERVATIONS DURING BIOMONITORING IN OCTOBER 1993.



0075I01X
Box 3
FIG 2-1

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DEPARTMENT OF THE NAVY
ENGINEERING FIELD ACTIVITY, CHESAPEAKE
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON, DC
WASHINGTON NAVY YARD

INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
SITE 8 - NITROGLYCERIN PLANT OFFICE
OCTOBER, 1994 - BIOMONITORING SAMPLING LOCATIONS

NORTHDIV FOR COMMANDER, NAVFAC

ISSUED: JANUARY, 1995

SEAL AREA

REV.	DESCRIPTION	PREP BY	DATE	APPRVD

DSGN: DR: CHK:
SUPV: CH ENG:
SUBMITTED BY: (TITLE)
(TITLE NUMBER) (CAT.)
CONSURV: NO:
DW: NO:
FYR: DIR:
OFFICER IN CHARGE
APPROVED DATE

SAT TO DATE

CODE I.D. NO. 86001
SCALE : AS SHOWN
SPEC. NO. 84 - NA
CONSTRN. CONTR. NO. NA
NAVFAC DRAWING NO. NA
SHEET 1 OF 1
SIZE: D
DIS. SH. NO. FIGURE 2-1

additional analysis or verification of periphyton identification is required. Any remaining slides collected at a given sampling location were discarded.

2.3 BENTHIC MACROINVERTEBRATE SAMPLING

Benthic macroinvertebrates were sampled with a Petite Ponar grab sampler at Transects 1-5, 7, 10, and the two control sites. Samples were sieved in the field, preserved, and transported to the laboratory for identification and enumeration. Standard methods described in APHA (1989) and Lind (1979) for collecting benthos with a Ponar grab sampler and counting benthic macroinvertebrates were employed.

2.4 FISH SAMPLING

2.4.1 Fish Surveys

No systematic fish surveys have been conducted at the three study sites since October 1992. Surveys carried out in July 1992 (by the U.S. Fish and Wildlife Service) and October 1992 (by Halliburton NUS) indicated that fish species diversity and abundance were very low at all sites and that electrofishing samples revealed little about community structure. In October 1992, for example, two species [*Gambusia holbrooki* (eastern mosquitofish) and *Fundulus heteroclitus* (mummichog)] comprised approximately 90 percent of the more than 300 fish collected at the Site 8 pond (Coastal Environmental Services, 1992; Halliburton NUS, 1993b).

Although the systematic fish surveys (i.e., timed surveys at fixed sampling transects that yield catch-per-unit-effort values and estimates of population abundance) were abandoned after two quarters, a species list and notes on occurrence were maintained for each of the three sampling locations, based on fish collections made for mercury analyses. This provided a measure of fish species richness (the total number of species captured at each site) and a crude measure of population abundance (i.e., "common," "uncommon," or "rare") for fish species at each of the three study areas.

2.4.2 Fish Sampling for Lead and Mercury Residues

No attempt was made to collect fish for bioassays in January (winter) 1995. The revised Biomonitoring Plan (Halliburton NUS, 1993a) did not specify winter fish sampling. When water temperatures are very low, as they are in Maryland in January and February, fish become inactive and are difficult to capture with conventional passive-capture gear such as gill nets and fish traps (Hubert, 1983).

Combination sampling techniques were employed in April and October 1994 in an effort to collect enough fish for a thorough comparative analysis of lead and mercury body burdens. Baited trap nets were set at the Site 8 pond, left overnight, and retrieved the following day. Trap nets were set perpendicular to shore in 1 to 3 feet of water, just below the surface. Trap nets were of conventional design with a leader and two wings directing fish to the baited heart of the net.

Minnow traps baited with cottonseed cake were set at the Site 8 study site and both control sites, left overnight, and were retrieved the following day. A 100-foot-long floating monofilament gill net was also used to collect fish at the Stump Neck beaver pond control site. The gill net was hung between two snags in a relatively open part of the pond in the afternoon and retrieved the following morning.

Electroshocking was employed to collect fish at the Site 8 study site and the Mattawoman Creek control site. Electrofishing was relatively effective at both sites in October 1994, resulting in the collection of large numbers of *Gambusia* at the Site 8 pond and higher-than-normal numbers of fish from Mattawoman Creek.

The original Biomonitoring Plan (Halliburton NUS, 1992a) called for collections of four fish species (largemouth bass, brown bullhead, and mosquitofish/mummichog) representing three trophic levels for analysis of mercury residues. When it became apparent that the target species would be difficult to collect consistently, designated surrogate species [such as bluegill and warmouth for largemouth bass and Notropid (shiner) minnows for mosquitofish/mummichog] were often employed (Halliburton NUS, 1993c; 1993d). After October 1993, the goal of the fish sampling was to collect sufficient numbers of fish to adequately characterize the extent of mercury (and later lead) contamination. To the extent practicable, fish representing three trophic levels were collected: top-of-the-food-chain predator, bottom-feeding omnivore, and surface-feeding insectivore.

In April and October 1994, 123 fish representing 11 species were collected at the 3 sites. No effort was made to assign fish to trophic levels, but a variety of species with very different feeding strategies were collected. All fish retained for bioassays were placed on ice and shipped to Gascoyne Laboratories, Incorporated, for analysis of lead and mercury residues in tissue.

2.4.3 Turtle Sampling for Lead and Mercury Residues

Painted turtles (*Chrysemys picta*) that were unintentionally drowned in trap nets at Site 8 (incident to fish sampling) in April and October 1994 were retained for analysis of mercury and lead residues in tissue. A number of other turtles were released unharmed. In April, two turtles were dissected, their livers removed, placed in a glass vial on ice, and shipped to Gascoyne Laboratories, Inc., for analysis of lead and mercury

residues. In October, samples of liver and muscle were obtained from two turtles that died in Site 8 trap nets, and shipped to Gascoyne Laboratories for analysis of lead and mercury residues.

3.0 BIOMONITORING RESULTS AND DISCUSSION

3.1 WATER QUALITY

Water quality data collected at Transects 1, 4, 7, 10 and the two control sites for February 1995 are presented in Table 3-1. Water temperatures in the Site 8 pond on February 2, 1995 ranged from 4.7°C to 5.7°C. The water temperature at Transect 10, which is located in a tributary stream northeast of Site 8, was 5.3°C. The water temperature at Control Site 2 (4.9°C) was comparable to that observed in the Site 8 pond, while the water temperature at Control Site 1 was slightly higher (6.1°C). Water temperatures were lower in the Site 8 pond during the winter 1994 sampling round (on January 27, 1994), ranging from 0.7°C to 1.1°C, while temperatures at Control Sites 1 and 2 were 0°C and 0.4°C, respectively.

DO concentrations in the Site 8 pond in February 1995 were high, ranging from 10.4 mg/L to 10.8 mg/L. The DO concentration was slightly lower at Transect 10 (9.8 mg/L) and Control Site 1 (9.7 mg/L). The highest DO concentration, 11.9 mg/L, was measured at Control Site 2. The high DO levels observed at Site 8 and the two control sites in February 1995 reflect the fact that DO concentrations vary inversely with water temperature and are generally highest in winter. High DO levels were also observed at all sites in January 1994 (Halliburton NUS, 1994a) and January 1993 (Halliburton NUS, 1993c), but in the winter 1994 and winter 1993 sampling rounds, the two control sites showed consistently higher DO concentrations than the Site 8 stations.

DO concentrations in winter and spring in the Site 8 pond are more than adequate to support a variety of aquatic life (Halliburton NUS, 1993c; 1993d; 1994a; 1994b). DO concentrations in the Site 8 pond have typically been lower (<5.0 mg/L) in the summer, when high water temperatures result in lower DO levels, and in fall when increased biological oxygen demand (from decaying vegetation and shed leaves) depresses dissolved oxygen levels (Halliburton NUS, 1993b; 1993c; 1993f; 1994c). Annual temperature and DO regimes in the Site 8 pond are not suitable for sensitive macroinvertebrate and fish species with demanding habitat requirements.

As in earlier quarterly rounds of biomonitoring, water samples were taken from the Site 8 pond and the two control sites in February 1995 for measurements of total organic carbon (TOC) and total hardness (as $CaCO_3$). TOC values for the three Site 8 stations and Transect 10 in February 1995 were the same, 4.0 mg/L (see Table 3-1). The TOC value at both control sites was 5.0 mg/L. TOC values were higher in January 1994, ranging from 15.0 to 18.0 mg/L at the three transects in the Site 8 pond, while TOC levels

TABLE 3-1

WATER QUALITY DATA - FEBRUARY 2, 1995
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Station	DO (mg/L)	Temp (°C)	pH	Cond (μmhos)	TOC (mg/L)	Total Hardness (as $CaCO_3$) (mg/L)
Transect 1	10.4	4.7	6.9	322	4.0	55.0
Transect 4	10.4	5.1	6.9	364	4.0	69.0
Transect 7	10.8	5.7	7.2	333	4.0	41.0
Transect 10	9.8	5.3	6.9	361	4.0	53.0
Control Site 1 (Stump Neck Beaver Pond)	9.7	6.1	6.3	115	5.0	24.0
Control Site 2 (Mattawoman Creek)	11.9	4.9	6.5	125	5.0	31.0

averaged 7.0 mg/L at Control Site 1 and 9.5 mg/L at Control Site 2. The reason for this change is unclear, but lower TOC values are probably related to lower rainfall in winter 1995 and reduced organic input (both dissolved and particulate organic matter) from the watershed. Total organic carbon is a measure of the total amount of organic material in a sample, such as suspended organic matter in the water column. In aquatic systems, organic carbon reduces the uptake and toxicity of contaminants through adsorption of contaminants to surfaces of organic particles.

Total hardness ranged from 41.0 to 69.0 mg/L at Transects 1, 4, 7, and 10 in February 1995. These values are indicative of relatively soft water (low in dissolved ions with minimal buffering capacity) (Lind, 1979; Drever, 1982). Hardness values measured in February 1995 samples from Site 8 were consistent with those recorded in 1993 and 1994. Control Site 1 hardness measurements averaged 24.0 mg/L in February 1995. Hardness in samples from Control Site 2 averaged 31.0 mg/L.

The pH of natural waters is governed to a large extent by the interaction of hydrogen ions arising from the dissociation of carbonic acid (H_2CO_3) and hydroxyl ions resulting from hydrolysis of bicarbonate (HCO_3) (Wetzel, 1975). As a result, there is a close relationship between pH and total hardness (as $CaCO_3$). The pH of Site 8 pond water is typically circumneutral (6.5 to 7.2 in 1994 and 1995), while the pH of the two control sites is typically lower, ranging from 5.7 to 6.9 in 1994 and 1995 (Halliburton NUS, 1994a; 1994b; 1994c; 1995). The toxicity of lead, which has been identified as a potential contaminant in the Site 8 pond, decreases as water hardness and pH increase (USEPA, 1984). In water, lead is most soluble and bioavailable under conditions of low pH, low organic content, and low hardness (Eisler, 1988; Sorensen, 1991), suggesting that reduced solubility is in part responsible for the reduction in toxicity. Given the hardness and pH levels typically measured in the Site 8 pond and the two control sites, lead should be slightly less soluble and less available to biota at Site 8 than at the two control sites, assuming the same level of contamination in water and sediments.

Conductivity was measured over the source of the biomonitoring study because it provides an indirect measure of salinity and because it determines, in large degree, the effectiveness of electrofishing. Because conductivity increases as concentrations of dissolved cations and anions in water increase, it is also closely related to levels of total dissolved solids and hardness. The relationship between conductivity and total hardness is obvious from the values in Table 3-1. The fact that conductivity measurements were higher at Site 8 than the two control sites is indicative of higher salinities (but still freshwater), higher concentrations of total dissolved solids and total hardness, and better electrofishing efficiency.

3.2 PERIPHYTON

In February 1995, average periphyton (attached algae) densities in the Site 8 pond ranged from 2,988 cells/cm^2 at Transect 1 to 34,394 cells/cm^2 at Transect 2. The average periphyton density (mean of 12 samples from four Site 8 transects) was 18,294 cells/cm^2. Tables A-1 through A-24, Appendix A, contain complete results of the February 1995 periphyton sampling.

Baccillariophyta (diatoms), Chlorophyta (green algae), and Cyanophyta (blue-green algae) dominated periphyton counts in February 1995, making up 58.3, 22.0, and 17.1 percent, respectively, of periphyton collected. Chrysophyta (golden-brown algae) were less numerous, making up 1.3 percent of periphyton collected. Three relatively-obscure periphyton groups–Cryptophyta, Euglenophyta, and Pyrrophyta–were present in small numbers (< 1 percent).

Diatoms and green algae made up the bulk of biomass in Site 8 periphyton samples in February 1995. Diatoms comprised more than 90 percent, by weight, of samples collected, while green algae made up approximately 6 percent. Diatoms are ubiquitous in a wide variety of freshwater and marine habitats, and are often associated with the littoral zones of lakes and ponds as well as the bottoms of streams (Whitford and Schumacher, 1973).

A total of 33 unique periphyton genera (one unidentified blue-green algae genus was not included in this total) representing seven divisions were collected at Site 8 in February 1995. Diversity measures (numbers of genera and divisions/phyla present) were lower in winter (January) 1994 sampling: 27 genera were collected representing five divisions. The most striking difference between winter (February) 1995 and winter (January) 1994 periphyton samples was the increase in 1995 in the relative abundance of diatoms and the concomitant decrease in blue-green and golden-brown algae. The significance of this shift in community structure is unclear.

Fourteen diatom genera, eight green algae genera, seven blue-green algae genera, one chrysophyte ("golden-brown" algae), one cryptophyte, one euglenophyte, and one pyrrhophyte (dinoflagellate) were present in Site 8 samples in February 1995. The following genera were most abundant in samples: the diatom *Surirella* (3,319 cells/cm^2), the diatom *Cyclotella* (2,911 cells/cm^2), the diatom *Navicula* (2,310 cells/cm^2), and the green algae *Chlorella* (1,664 cells/cm^2). *Oscillatoria* and *Synechococcus*, both blue-green algae, dominated Site 8 periphyton samples in January 1994.

The diatom *Surirella*, the most abundant genus in February Site 8 samples, is a widespread form comprising nearly 200 species that are found in fresh, brackish, and marine waters. There are about 35 freshwater

species in the U.S. (Smith, 1950). *Surirella* is a benthic genus that is commonly found in or near sediments in lakes, ponds, and slow-flowing streams (Patrick, 1977). It is listed as a "clean water" algae by APHA (1989).

Cyclotella, *Navicula*, and *Chlorella* are listed by Palmer (1975) as pollution-tolerant genera. Because *Cyclotella* and *Navicula* are listed as "clean water algae" by the APHA (1989), the value of these genera as indicators of eutrophication or pollution is questionable; however, there is overwhelming evidence to suggest that conditions in the Site 8 pond favored growth and production of a variety of pollution-tolerant periphyton in February 1995. Many of the genera present in February Site 8 samples are known to be pollution-tolerant forms, among them the diatom *Synedra*, the green algae *Scenedesmus* and *Chlorella*, and the blue-green algae *Oscillatoria*.

In February 1995, the periphyton community of Control Site 1 (Stump Neck beaver pond) was dominated by diatoms (95 percent of total), with one diatom genus (*Cyclotella*) making up 58 percent of all algae collected. This was in marked contrast to winter 1994, when Chrysophyta (golden-brown algae) were most numerous. Total (mean) density was 13,843 cells/cm^2 in winter (February) 1995, compared to 8,439 cells/cm^2 in winter (January) 1994. Diversity measures were similar in both years and were comparatively low: 11 genera from two divisions were present in winter 1995, and 10 genera from three divisions were present in winter 1994.

The periphyton community of Control Site 2 (Mattawoman Creek) was characterized by relatively low measures of density and diversity in February 1995. The total mean density was only 2,755 cells/cm^2, and 12 genera representing two divisions, diatoms and green algae, were collected. No periphyton samples were obtained from Mattawoman Creek in winter 1994 because the artificial substrate samplers were lost (stolen or vandalized).

Periphyton density and diversity in samples collected from April 1993 through February 1995 are summarized in Figures 3-1 and 3-2. The periphyton of Site 8 have shown distinct seasonal differences in population abundance and community structure. Although the degree of change between seasons indicated by these data may be exaggerated, the basic trends are probably representative of periphyton community changes in the Site 8 pond and other small ponds in the region.

Periphyton densities in ponds are typically highest in spring and fall (when moderate temperatures stimulate growth and reproduction of algae) and lowest in winter and summer (when temperature extremes limit growth and reproduction of algae). Anomalies, such as the density "spike" in July 1994 (see Figure 3-1) are often the result of algae blooms. Extraordinarily-high algal densities in July 1994 were the result of a bloom

FIGURE 3-1

PERIPHYTON DENSITY (cells/cm^2)
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

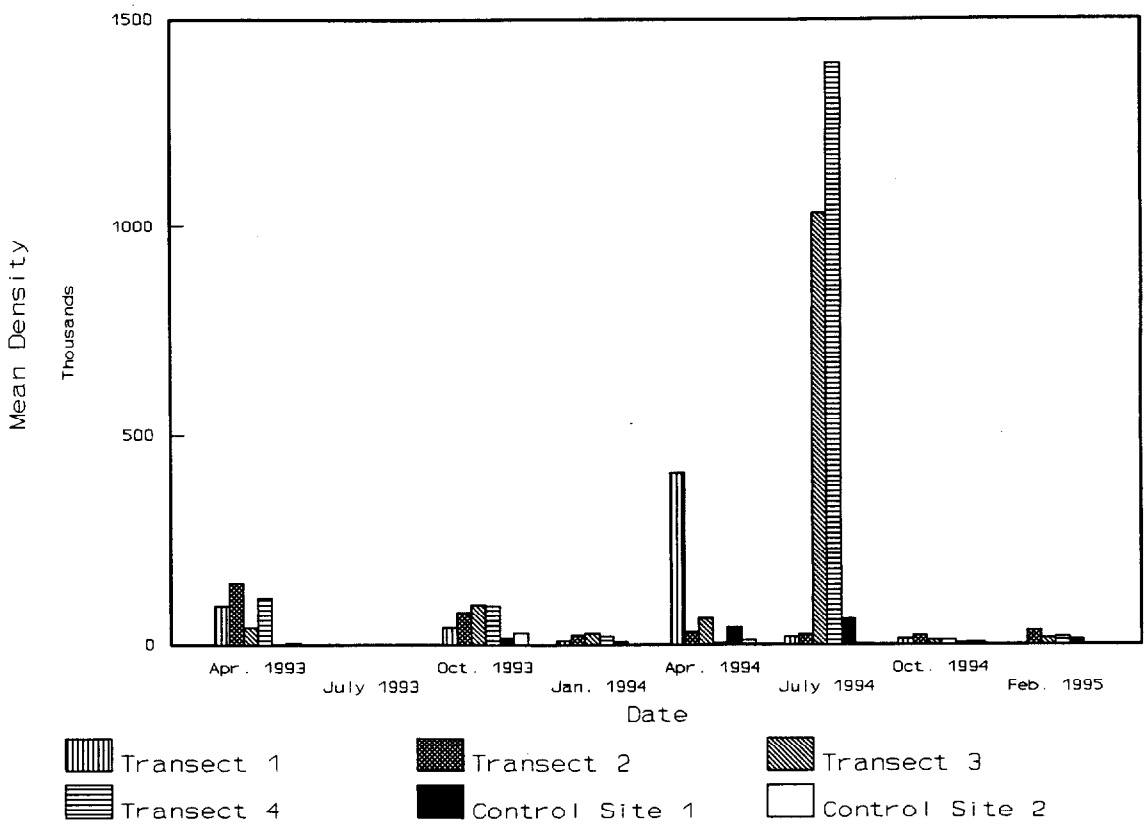
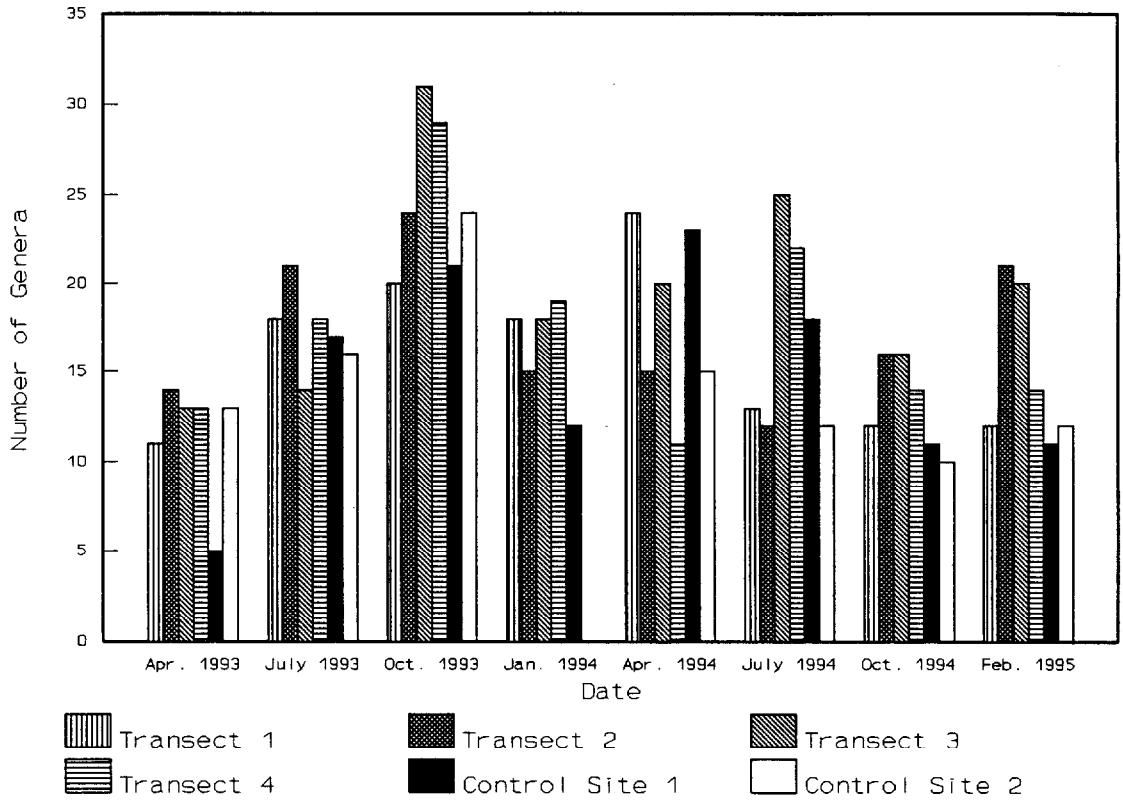


FIGURE 3-2

PERIPHYTON DIVERSITY
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND



of the nuisance blue-green algae *Oscillatoria*. Community structure patterns (i.e., relative abundance of particular genera and divisions/phyla, presence or absence of pollution-tolerant and intolerant forms, proportions of benthic and planktonic genera) are much more difficult to interpret and have only been touched on in this biomonitoring report and earlier reports.

3.3 BENTHIC MACROINVERTEBRATES

The Site 8 pond, with its rooted aquatic vegetation (in shallows and around pond margins) and soft, gently-sloping bottom (consisting of silt, muck, and organic detritus) is typical of tidally-influenced freshwater ponds in the Potomac River estuary (Maryland DNR, 1981). Since April 1993, the bottom substrate has been characterized as unconsolidated silt and mud (Coastal Environmental Services, 1993a; 1993b; 1993c; 1994a; 1994b; 1994c; 1994d). Table 3-2 lists densities and relative proportions of macroinvertebrates found in benthic sediments from Site 8 and the two control sites in 1994 and February 1995.

In January 1994, macroinvertebrate density and diversity were low in benthos collections from all Site 8 transects. Densities at the Site 8 transects ranged from 53 organisms/m^2 at Transect 2 to 654 organisms/m^2 at Transect 7. Diversity was also low in January 1994 at all Site 8 transects, with no more than four taxa collected at any transect. (In this report, the term "diversity" is used in its loosest sense: the number of taxa observed at a given location is technically a measure of richness.)

In April 1994, benthic macroinvertebrate densities were somewhat higher at all Site 8 transects, ranging from 171 organisms/m^2 at Transect 5 to 751 organisms/m^2 at Transect 7. Macroinvertebrate densities were higher at Transect 10, averaging 875 organisms/m^2. Macroinvertebrate diversity was low, with only three groups represented: oligochaetes (the genus *Branchuria* and the families Tubificidae and Lumbriculidae), chironomids (of the sub-family Chironominae), and a single dipteran of the sub-family Chaoborinae, (presumably the phantom-midge larvae, *Chaoborus*).

Density and diversity of macroinvertebrates in Site 8 benthos samples continued to be low in July 1994. Densities ranged from 139 organisms/m^2 at Transect 2 to 387 organisms/m^2 at Transect 7. Only four macroinvertebrate groups were present: oligochaetes, chironomids, dipterans (the phantom-midge larvae, *Chaoborus*), and isopods (*Asellus* sp.).

In October 1994, benthic macroinvertebrate densities at Site 8 were comparable to those observed earlier in the year, ranging from 115 organisms/m^2 at Transect 7 to 771 organism/m^2 at Transect 4. Only two groups were present: Oligochaetes (from the genus *Branchiura* and the family Tubificidae) and dipterans

TABLE 3-2

DENSITY (NO./m^2) AND RELATIVE ABUNDANCE (%) OF BENTHIC MACROINVERTEBRATES INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER

Taxon	Transect 1					Transect 2				
	Jan 94	Apr 94	Jul 94	Oct 94	Feb 95	Jan 94	Apr 94	Jul 94	Oct 94	Feb 95
Corbicula sp.										
Pisidium sp.										
Sphaerium sp.										
Lymnaea sp.										
Physa sp.										
Physella sp.										
Gyraulus sp.										
Helisoma sp.										
Ferissia sp.										
Oligochaeta (unident)										
Lumbriculidae	72 (24.9)	5 (1.6)			10 (2.1)		5 (1.3)	29 (20.9)		
Tubificidae	125 (43.3)	273 (87.5)	57 (27.9)	163 (55.1)	442 (93.6)	29 (54.7)	347 (87.8)	57 (41.0)	171 (79.9)	57 (49.6)
Branchiura sp.	63 (21.8)	5 (1.6)		24 (8.1)	10 (2.1)		23.8 (6.1)	19 (13.7)	5 (2.3)	
Hypaniola sp.										
Gammarus sp.										
Asellus sp.										
Ephemerella sp.										
Gomphus sp.										
Helocordulia sp.										
Plathemis sp.										
Sympetrum sp.										
Calopteryx sp.										
Notonecta undulata										
Sialis										
Polycentropodidae										
Diptera (adult)										
Diptera (larvae)										
Chaoborus sp.			114 (55.9)	109 (36.8)	5 (1.1)	5 (9.4)		29 (20.9)	33 (15.4)	48 (41.7)
Chironomidae (unident)										
Tanypodinae									5 (2.3)	5 (4.3)
Chironominae	29 (10.0)	29 (9.3)	33 (16.2)		5 (1.1)	19 (35.8)	19 (4.8)	5 (3.6)		5 (4.3)
Totals	289	312	204	296	472	53	395	139	214	115

TABLE 3-2 (Continued)
DENSITY (NO./m^2) AND RELATIVE ABUNDANCE (%) OF BENTHIC MACROINVERTEBRATES
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER

Taxon	Transect 3					Transect 4				
	Jan 94	Apr 94	Jul 94	Oct 94	Feb 95	Jan 94	Apr 94	Jul 94	Oct 94	Feb 95
Corbicula sp.										
Pisidium sp.										
Sphaerium sp.										
Lymnaea sp.										
Physa sp.										
Physella sp.										
Gyraulus sp.										
Helisoma sp.										
Ferissia sp.										
Oligochaeta (unident)										
Lumbriculidae	28 (48.3)	10 (3.0)	48 (12.2)			19 (24.7)				10 (6.2)
Tubificidae	10 (17.2)	285 (85.6)	219 (55.9)	152 (72.7)	171 (94.5)	58 (75.3)	532 (94.8)	181 (76.0)	523 (67.8)	133 (82.1)
Branchiura sp.	10 (17.2)	38 (11.4)	29 (7.4)	19 (9.1)					10 (1.3)	
Hypaniola sp.										
Gammarus sp.										
Asellus sp.										
Ephemerella sp.										
Gomphus sp.										
Helocordulia sp.										
Plathemis sp.							10 (1.8)			
Sympetrum sp.										
Calopteryx sp.										
Notonecta undulata										
Sialis										
Polycentropodidae										
Diptera (adult)										
Diptera (larvae)										
Chaoborus sp.			86 (21.9)	38 (18.2)	10 (5.5)			38 (16.0)	219 (28.4)	19 (11.7)
Chironomidae (unident)										
Tanypodinae									19 (2.5)	
Chironominae	10 (17.2)		10 (2.6)				19 (3.4)	19 (8.0)		
Totals	58	333	392	209	181	77	561	238	771	162

TABLE 3-2 (Continued)
DENSITY (NO./m^2) AND RELATIVE ABUNDANCE (%) OF BENTHIC MACROINVERTEBRATES
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER

Taxon	Transect 5					Transect 6				
	Jan 94	Apr 94	Jul 94	Oct 94	Feb 95	Jan 94*	Apr 94	Jul 94	Oct 94*	Feb 95*
Corbicula sp.										
Pisidium sp.										
Sphaerium sp.										
Lymnaea sp.										
Physa sp.										
Physella sp.										
Gyraulus sp.										
Helisoma sp.										
Ferissia sp.										
Oligochaeta (unident)										
Lumbriculidae	39 (26.9)	10 (5.8)			10 (2.3)					
Tubificidae	96 (66.2)	161 (94.2)	219 (67.6)	523 (71.4)	409 (93.1)		276 (90.5)	209 (64.5)		
Branchiura sp.	10 (6.9)				10 (2.3)			57 (17.6)		
Hypaniola sp.								10 (3.1)		
Gammarus sp.										
Asellus sp.										
Ephemerella sp.										
Gomphus sp.										
Helocordulia sp.										
Plathemis sp.										
Sympetrum sp.										
Calopteryx sp.										
Notonecta undulata										
Sialis										
Polycentropodidae										
Diptera (adult)										
Diptera (larvae)										
Chaoborus sp.			95 (29.3)	209 (28.6)	10 (2.3)			10 (3.1)		
Chironomidae (unident)										
Tanypodinae										
Chironominae			10 (3.1)				29 (9.5)	38 (11.7)		
Totals	145	171	324	732	439	0	305	324	0	0

*Not sampled this quarter

TABLE 3-2 (Continued)
DENSITY (NO./m^2) AND RELATIVE ABUNDANCE (%) OF BENTHIC MACROINVERTEBRATES
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER

Taxon	Transect 7					Transect 10				
	Jan 94	Apr 94	Jul 94	Oct 94	Feb 95	Jan 94	Apr 94	Jul 94	Oct 94	Feb 95
Corbicula sp.										
Pisidium sp.										
Sphaerium sp.										
Lymnaea sp.										
Physa sp.										
Physella sp.										
Gyraulus sp.										
Helisoma sp.										
Ferissia sp.										
Oligochaeta (unident)										
Lumbriculidae	10 (1.5)					134 (35.2)				95 (7.8)
Tubificidae	615 (94.1)	656 (87.4)	206 (53.2)	48 (41.7)	105 (100)	237 (62.2)	855 (97.7)	2,375 (81.7)	580 (85.8)	1,074 (88.2)
Branchiura sp.			19 (4.9)			10 (2.6)	10 (1.1)	19 (0.7)	86 (12.7)	38 (3.1)
Hypaniola sp.										
Gammarus sp.			114 (29.5)					10 (0.3)		
Asellus sp.								19 (0.7)		
Ephemerella sp.										
Gomphus sp.										
Aeshnidae										
Helocordulia sp.										
Plathemis sp.							10 (1.1)			
Sympetrum sp.										
Calopteryx sp.										
Notonecta undulata										
Sialis										
Polycentropodidae										
Diptera (adult)										
Diptera (larvae)										
Chaoborus sp.			29 (7.5)	67 (58.3)				10 (0.3)		10 (0.9)
Chironomidae (unident)										
Tanypodinae										
Chironominae	29 (4.4)	95 (12.6)	19 (4.9)					475 (16.3)	10 (1.5)	
Totals	654	751	387	115	105	381	875	2,908	676	1,217

TABLE 3-2 (Continued)
DENSITY (NO./m^2) AND RELATIVE ABUNDANCE (%) OF BENTHIC MACROINVERTEBRATES
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER

Taxon	Control 1					Control 2				
	Jan 94	Apr 94	Jul 94	Oct 94	Feb 95	Jan 94	Apr 94	Jul 94	Oct 94	Feb 95
Corbicula sp.										
Pisidium sp.										
Sphaerium sp.	29 (2.5)	19 (1.3)				10 (0.6)			10 (1.0)	
Lymnaea sp.						10 (0.6)				
Physa sp.										
Physella sp.										
Gyraulus sp.										
Helisoma sp.										
Ferissia sp.						10 (0.6)				
Oligochaeta (unident)										
Lumbriculidae						67 (4.2)				
Tubificidae	1,049 (90.7)	1,178 (81)	504 (80.3)	960 (75.3)	1,425 (98.0)	914 (56.5)	257 (74.9)	1,767 (97.4)	789 (75.4)	409 (76.7)
Branchiura sp.										
Hypaniola sp.										
Gammarus sp.	19 (1.6)	10 (0.7)		276 (21.6)		10 (0.6)	57 (16.6)		190 (18.1)	10 (1.9)
Asellus sp.										
Ephemerella sp.									10 (1.0)	
Gomphus sp.						10 (0.6)				
Aeshnidae				10 (0.8)						
Helocordulia sp.	10 (0.9)									
Plathemis sp.		10 (0.7)								
Sympetrum sp.		10 (0.7)								
Calopteryx sp.										
Notonecta undulata										
Sialis						10 (0.6)			19 (1.8)	
Polycentropodidae										57 (10.7)
Diptera (adult)										
Diptera (larvae)	10 (0.9)									
Chaoborus sp.				10 (0.8)					10 (1.0)	
Chironomidae (unident)										
Tanypodinae				19 (1.5)	29 (2.0)					57 (10.7)
Chironominae	39 (3.4)	226 (15.7)	124 (19.7)			576 (35.6)	29 (8.5)	48 (2.6)	19 (1.8)	
Totals	1,156	1,455	628	1,275	1,454	1,617	343	1,815	1,047	533

from the sub-family Chaoborinae (presumably *Chaoborus*, the phantom-midge larvae) and the sub-family Tanypodinae (also a midge).

In February 1995, benthic macroinvertebrate densities at Site 8 ranged from 105 organisms/m^2 at Transect 7 to 472 organisms/m^2 at Transect 1. Macroinvertebrate densities were higher at Transect 10, averaging 1,217 organisms/m^2. As in the previous four quarters, benthos samples from Site 8 were dominated by oligochaetes and larval dipterans [phantom-midge larvae (*Chaoborus*) and chironomid larvae]. Oligochaetes made up 49.6 (Transect 2) to 100.0 percent (Transect 7) of macroinvertebrates collected at Site 8 transects in February.

Oligochaetes and chironomids have been the most common organisms in Site 8 collections since January 1993 (Halliburton NUS, 1993d; 1993e; 1993f, 1994a; 1994b; 1994c; 1995). Oligochaetes made up 28 to 100 percent of macroinvertebrates collected from a given Site 8 transect in January, April, July, and October 1994 and were represented by two largely-aquatic families, Tubificidae and Lumbriculidae. Aquatic oligochaetes are burrowing detritivores, well suited for silt and mud substrates. Most aquatic oligochaetes are able to tolerate low DO concentrations (Pennak, 1978).

The tubificid oligochaete *Branchiura*, frequently collected at Site 8 since January 1993, is often found in oxygen-poor, lake-bottom sediments. This genus has unusual gill-like structures on the lower part of its body that supplement the "normal" respiration at the capillary-rich, body surface (Pennak, 1978). Oligochaete species are variable in their ability to withstand other environmental stresses. Several genera are very stress-resistant (e.g., *Tubifex* and *Limnodrilus*) and may develop tremendous populations in the absence of other aquatic organisms which have been destroyed by pollution.

The phantom-midge larvae *Chaoborus*, collected for the first time in January 1994 in small numbers, is a predator that feeds on microcrustaceans and insect larvae. *Chaoborus* is abundant in large ponds and reservoirs "everywhere" according to Pennak (1978) and shows pronounced daily migratory movements from bottom muds (during the day) to open water (at night). *Chaoborus* uses specialized hydrostatic organs to extract oxygen from sediments and water that are low in DO (Pennak, 1978).

For reasons that are unclear, *Chaoborus* became an important component of Site 8 macrobenthos in July 1994, appearing in samples from all six transects (plus Transect 10) and making up more than 20 percent of all organisms collected. In October 1994, *Chaoborus* was again present in samples from all Site 8 transects. *Chaoborus* made up approximately 29 percent of all macroinvertebrates collected at Site 8 in October 1994. In February 1995, *Chaoborus* was present in samples from five Site 8 transects, but densities were somewhat lower than in July or October 1994.

The marked decrease in densities and diversity of macroinvertebrates at all Site 8 transects that occurred between January and April 1993 was attributed to: (1) unusually-heavy rains in the spring of 1993 in the Indian Head area, and (2) the installation of a weir-water control structure in the pond (Halliburton NUS, 1993d). Heavy spring rains and flooding probably resulted in flushing of the drainage basin, with many macroinvertebrates (excluding certain burrowing forms, such as oligochaetes) being driven downstream. The benthos of Site 8 is particularly vulnerable to displacement because there are few habitat-forming structures (stumps, logs, boulders, pilings) in the pond that provide refuge from the current. Also, the substrate is mostly loose, unconsolidated material that is easily disturbed, resuspended, and transported downstream.

The installation of a weir/water control structure in the Site 8 pond may have also contributed to the low numbers and diversities of macroinvertebrates observed after January 1993. A cofferdam was put in place on April 19, 1993, and the area behind the cofferdam was subsequently drained (J. Bossart, Indian Head Naval Ordnance Station, personal communication with P. Moore, Halliburton NUS). A permanent weir was installed on April 23, 1993. The pond level, which had been unusually high as a result of torrential spring rains, fell to the level of the weir after it was installed. The degree to which these activities resulted in displacement or disturbance of macroinvertebrates is unknown, but some displacement of macroinvertebrates may well have occurred.

Based on the results of 1993, 1994, and (February) 1995 benthos surveys, the macroinvertebrate benthofauna of the Site 8 pond can only be described as depauperate, with low densities of benthic organisms and low taxa richness (or "diversity"). It is unknown whether these low densities are an indication of slow (post-flooding and weir installation) recolonization, or a long-term change in benthic community structure caused by changes in the composition of the bottom substrate of the pond.

Very few comprehensive studies of benthos in tidal freshwaters have been conducted (see review in Odum et al., 1984). Diaz and Boesch (1977) and VIMS (1978) investigated effects of development on benthos in the James River, Virginia, a river similar to the Potomac in terms of discharge and drainage area (Van der Leeden et al., 1990) and, one presumes, trophic state, nutrient loads, water temperature regimes, and biota, given their geographical proximity and the similarity of the two watersheds.

Both investigations (Diaz and Boesch, 1977; VIMS, 1978) revealed that the benthos of the James River and adjacent freshwater marshes were dominated numerically by tubificid oligochaetes and larval chironomids, and both suggested that the asiatic clam *Corbicula* was the most important component of benthic biomass. Members of the order Diptera (which includes flies, mosquitoes, and midges) are the only insect larvae found in significant numbers in the fresh-to-brackish waters of the Potomac estuary, which includes

Mattawoman Creek and environs (Maryland DNR, 1981). Thus, the numerical dominance of oligochaetes and chironomids and the low diversity of aquatic insect larvae at Site 8 pond is not surprising, and is not necessarily indicative of a macroinvertebrate community that has been impacted by deteriorating water quality. *Corbicula* have been found in small numbers at Transect 10, the transect which lies in a tributary of the Site 8 pond, but the substrate of the pond does not appear to be firm enough or stable enough to support large numbers of these clams.

Diaz and Boesch (1977) suggested that the low species richness and simple community structure generally observed in benthic communities of tidal freshwater marshes and ponds result from the homogeneity of the habitat, and in particular featureless sand or mud substrates such as that found in the Site 8 pond. Many aquatic insect larvae (e.g., many caddisfly, mayfly, and stonefly genera) are closely associated with debris, leaf litter, gravel, crevices in rocks, and roots, leaves, and stems of aquatic plants. Diverse communities of aquatic insects are typically found in areas providing a diversity of habitats (or "niches") with acceptable temperature and oxygen regimes and abundant food.

Benthic macroinvertebrate samples collected from Control Site 1 (Stump Neck beaver pond) in February 1995 consisted of only two taxa, Tubificid oligochaetes (98 percent) and chironomids of the subfamily Tanypondinae. The total (mean) density was 1,454 organisms/m^2, comparable to that observed in January 1994 (1,156 organisms/m^2). Since April 1993, benthos collections from this control site have been characterized by low density, with no more than six taxa appearing in a given sampling round (quarter). Oligochaetes (mostly Tubificids) have been numerically dominant at this control site, making up 69 to 85 percent of benthic organism in 1993, and 75 to 91 percent of organisms in 1994.

In February 1995, four macroinvertebrate taxa were present in samples from Control Site 2 (Mattawoman Creek), with nearly 77 percent made up of Tubificid oligochaetes. A number of specimens of caddisfly from the family Polycentropodidae were collected for the first time in February. Larval Polycentropodidae are generally sedentary "net-spinning" caddisflies that live in streams and strain food particles from the current (Morse and Holzenthal, 1984).

Control Site 2 (Mattawoman Creek) showed more seasonal variability in macroinvertebrate density and diversity than either Site 8 or Control Site 1 in 1994 sampling, with sampling results that were occasionally baffling. For example, nine macroinvertebrate taxa were collected in January 1994 when the water temperature was 0.4°C (macroinvertebrate activity should have been nil), but only three taxa were collected in April 1994, when conditions (21°C water temperature) should have been conducive to movement, feeding, and reproduction of macroinvertebrates. Under normal circumstances, this increased activity would result in higher measures of density and diversity in benthic macroinvertebrate samples. Macroinvertebrates are

more susceptible to capture when they are more active. Although Mattawoman Creek proved to be a valuable control site for assessing lead and mercury levels in Site 8 fish over the course of this investigation, it was of limited value as a control site for evaluating macroinvertebrate communities.

3.4 FISH DIVERSITY

As noted in Section 2.4.1, plans to conduct systematic fish population surveys were abandoned because of the low species diversity and general scarcity of fish observed in July (U.S. Fish and Wildlife Service) and October 1992 samples. However, species captured in the course of collecting fish for mercury and lead analyses have been noted and compiled in site-specific species lists. Table 3-3 lists fish species collected to date from the Site 8 pond and the two control sites.

Species richness (as indicated by the number of species captured) is surprisingly high at the Site 8 pond, given its depth (uniformly shallow) and the lack of cover present, with 11 species collected since July 1992. All are common species of tidal freshwater creeks and ponds of the mid-Atlantic coast (Odum et al., 1984; Lee et al., 1980). The eastern mosquitofish, *Gambusia holbrooki*, appears to be the most abundant species in the Site 8 pond and its tributaries. *Gambusia holbrooki* favors vegetated areas of ponds, drainage ditches, sloughs, and backwaters of creeks and rivers over a soft mud substrate. It can tolerate water temperatures as high as 39°C (104°F) and is often found in degraded waters from which other native fish species have been eliminated (Rohde et al., 1994). Other species have been common [e.g., bluegill (*Lepomis macrochirus*) and brown bullhead (*Ameiurus nebulosus*)] to uncommon [e.g., largemouth bass (*Micropterus salmoides*)] in Site 8 collections. A new species, the white crappie (*Pomoxis annularis*), was collected at Site 8 in October 1994.

Two new species, largemouth bass and brown bullhead, both widespread in the Potomac River drainage (Lee et al., 1980, Maryland DNR, 1981), were collected at Control Site 1 (Stump Neck beaver pond) in October 1994. This brings to eight the total number of species collected at this location since 1992.

Three new fish species were also collected at Control Site 2 (Mattawoman Creek) in October 1994: largemouth bass, warmouth (*Lepomis gulosus*), and banded killifish (*Fundulus diaphanus*). These three species are all common inhabitants of Maryland waters (Lee et al., 1980; Maryland DNR, 1981). A total of 11 species has been collected at this site since 1993. One would expect species richness to be relatively high at this site because Mattawoman Creek is used year round by a variety of freshwater fish species and is used in spring and summer by a number of anadromous (migratory) fish species that move into its waters to spawn. Unlike the Site 8 pond and the Stump Neck beaver pond, Mattawoman Creek is an "open" system with no barriers to up- and downstream fish movement.

TABLE 3-3

FISH COLLECTED FROM SITE 8 AND CONTROL SITES
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Species	Site 8								Control Site 1 (Stump Neck Beaver Pond)						
	7-92	10-92	1-93	4-93	7-93	10-93	4-94	10-94	10-92	1-93	4-93	7-93	10-93	4-94	10-94
Anguilla rostrata													●		
Cyprinus carpio							●								
Notropis sp.						●							●	●	●
Notropis hudsonius															
Semotilus atromaculatus															
Erimyzon oblongus			●									●	●	●	●
Esox americanus												●			
Ameiurus nebulosus	●	●			●	●		●							●
Umbra pygmaea										●	●				
Fundulus diaphanus															
Fundulus heteroclitus	●	●	●	●											
Gambusia holbrooki	●	●	●			●		●							
Lepomis gibbosus		●					●						●	●	
Lepomis gulosus					●										
Lepomis macrochirus	●	●	●	●	●		●	●							
Micropterus salmoides	●														●
Pomoxis annularis								●							
Morone americana															

TABLE 3-3 (CONTINUED)
FISH COLLECTED FROM SITE 8 AND CONTROL SITES
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

SPECIES	Control Site 2 (Mattawoman Creek)						
	10-92	1-93	4-93	7-93	10-93	4-94	10-94
Anguilla rostrata							
Cyprinus carpio							
Notropis sp.			●				
Notropis hudsonius						●	
Semotilus atromaculatus					●		
Erimyzon oblongus		●					●
Esox americanus							
Ameiurus nebulosus						●	●
Umbra pygmaea							
Fundulus diaphanus							●
Fundulus heteroclitus							
Gambusia holbrooki							
Lepomis gibbosus					●	●	
Lepomis gulosus							●
Lepomis macrochirus					●	●	●
Micropterus salmoides							●
Pomoxis annularis							
Morone americana			●				

It was suggested in previous monitoring reports (Halliburton NUS, 1993c; 1993d) that the installation of a weir water-control structure at the Site 8 dam would reduce fish diversity in the Site 8 pond over time. This assumed that the weir would prevent fish (and invertebrates) from moving into the Site 8 pond from Mattawoman Creek, resulting in a fishery that is less diverse and more typical of a freshwater stream/pond than an estuary. It was also suggested that in the absence of recruitment from downstream, at least one species -- the mummichog (*Fundulus heteroclitus*) -- would likely decrease in relative abundance. The mummichog is able to reproduce and maintain population levels in freshwater impoundments under certain circumstances, but is more likely to flourish in brackish tidal waters (Scott and Crossman, 1973; Lee et al., 1980). The mummichog has not been collected at Site 8 since April 1993, and appears to have been eradicated from the Site 8 pond.

A number of authorities have suggested using the structural and functional attributes of fish communities as indicators of the health of aquatic ecosystems (Karr, 1981; Fausch et al., 1984; Angermeier and Karr, 1986; Fausch et al., 1990; Karr, 1991). These "rating" systems use different terminology (different metrics and indices) to measure aquatic habitat quality, but they have a number of criteria in common, among them:

- Species Richness and Composition
  - Total number of fish species/abundance of each species
  - Number/identity of darter species
  - Number/identity of sunfish species
  - Number/identity of sucker species
  - Number and identity of pollution-intolerant species
- Trophic Composition
  - Proportion of individuals as omnivores
  - Proportion of individuals as insectivores
  - Proportion of individuals as top carnivores

Regardless of the rating system employed, the Site 8 pond would be classified as a degraded or impaired aquatic community ("poor" or "fair" habitat, depending on the classification scheme used). The Site 8 pond has: (1) relatively low species richness (11 species collected to date) and generally low abundance of fish, (2) no darter (i.e., *Etheostoma* and *Percina*) species, (3) only three sunfish species (bluegill, pumpkinseed,

and warmouth), (4) no "intolerant" species (species, such as trout and sculpin that are intolerant of eutrophication/siltation/pollution), (5) a high proportion of pollution-tolerant species, such as brown bullhead and eastern mosquitofish, and (6) almost no "top carnivores" (e.g., bass and pickerel).

The fish community of the Site 8 pond is composed of hardy, pollution-tolerant species, such as the brown bullhead, the mosquitofish, and the common carp. Fish species with more demanding habitat requirements (i.e., those that cannot tolerate high temperatures and low DO levels) are conspicuously absent. But, as noted elsewhere in this report, this appears to be a function of physical and chemical factors (e.g., siltation and low DO) rather than metals contamination.

3.5 ANALYSIS OF MERCURY AND LEAD IN TISSUE OF AQUATIC ORGANISMS

Fish samples (whole-body) were collected during quarterly biomonitoring from October 1992 to October 1994 from Site 8 and two control sites for analysis of mercury residues in tissue. For each round of biomonitoring, all samples of each species collected were combined and homogenized; one analysis was then performed on each species sample. As shown on Table 3-4, the sample size (number of fish of a particular species) ranged from 1 to 75. Additionally, samples of other aquatic and semi-aquatic organisms (crayfish and leopard frogs of the genus *Rana*) were collected at various times in 1993 and analyzed for mercury residues. In April and October 1994, whole-body fish samples and (liver and muscle) turtle samples were split and analyzed for lead residues as well as mercury residues in tissue. All tissue samples were shipped on ice to Gascoyne Laboratories, Inc., for analysis.

EPA Method 7471 was used to determine the concentration of total inorganic mercury in each sample. EPA Method 7421 was used to determine the concentration of total inorganic lead in each sample. Analyses of fish were performed on homogenized whole body samples, rather than on fillets. The rationale for using whole body samples was the assumption that small prey species such as *Fundulus* and *Gambusia*, which made up the majority of fish collected from Site 8 during Phase I of this study, are almost always eaten whole by predatory fish, piscivorous birds, and piscivorous mammals.

Data from the two years of biomonitoring (October 1992 to October 1994) do not demonstrate any particular trend with respect to mercury concentrations in fish tissue (Table 3-4). For example, the data failed to demonstrate a marked difference in the concentrations of mercury measured in different fish species collected at a particular site (e.g., Site 8). Because mercury exhibits a tendency to biomagnify (increases in concentration at higher levels of a food chain), detection of higher concentrations of mercury in bluegill (a mid-food-chain organism that eats insects and small fish) than in *Gambusia* (an omnivore that eats zooplankton, insects, and some plant material) was anticipated. This has not been the case, however;

TABLE 3-4

MERCURY CONCENTRATIONS, SITE 8 AND CONTROL SITES
OCTOBER 1992 - OCTOBER 1994
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Organism	Mercury Concentration in mg/kg (sample size)						
	October 1992	January 1993	April 1993	July 1993	October 1993	April 1994	October 1994
SITE 8 POND							
Carp	--	--	--	--	--	0.03 (2)	--
Notropis (shiner)	--	--	--	--	0.05 (4)	--	--
Creek chubsucker	--	0.03 (1)	--	--	--	--	--
Brown bullhead	0.04 (3)	--	--	0.05 (2)	0.05 (1)	--	0.06 (2)
Fundulus (mummichog)	--	--	0.03 (8)	--	--	--	--
Gambusia (mosquitofish)	0.06 (16)	0.15 (4)	--	--	0.12 (36)	--	0.27 (75)
Pumpkinseed	--	--	--	--	--	0.09 (3)	--
Warmouth	--	--	--	0.23 (1)	--	--	--
Bluegill	0.02 (11)	0.02 (6)	0.06 (1)	0.09 (2)	--	0.07 (3)	0.07 (4)
White Crappie	--	--	--	--	--	--	0.06 (2)
Crayfish	--	--	--	0.07 (2)	0.09 (4)	--	--
Frog	--	--	0.03 (1)	--	--	--	--
Turtle (Liver)	--	--	--	--	--	1.3 (2)	0.35 (2)
Turtle (Muscle)	--	--	--	--	--	--	0.07 (2)
CONTROL SITE 1 (STUMP NECK BEAVER POND)							
American eel	--	--	--	--	0.11 (2)	--	--
Eastern mudminnow	--	--	0.07 (1)	--	--	--	--
Redfin pickerel	--	--	--	0.21 (1)	--	--	--
Notropis (shiner)	--	--	--	--	0.07 (4)	0.04 (4)	0.07 (2)
Creek chubsucker	--	--	--	0.09 (1)	0.11 (1)	--	0.07 (2)
Creek chub	--	--	--	--	--	--	--
Pumpkinseed	--	--	--	--	0.11 (1)	0.13 (1)	--
Largemouth bass	--	--	--	--	--	--	0.29 (1)
CONTROL SITE 2 (MATTAWOMAN CREEK)							
Notropis (shiner)	--	--	0.04 (2)	--	--	--	--
Spottail shiner	--	--	--	--	--	0.02 (1)	--
Creek chubsucker	--	0.03 (1)	--	--	--	--	0.03 (3)
Creek chub	--	--	--	--	0.02 (2)	--	--
Brown bullhead	--	--	--	--	--	0.05 (1)	<0.02 (2)
White perch	--	--	0.02 (1)	--	--	--	--
Pumpkinseed	--	--	--	--	0.01 (1)	0.29 (1)	--
Warmouth	--	--	--	--	--	--	0.14 (1)
Bluegill	--	--	--	--	0.03 (7)	0.04 (6)	<0.02 (3)
Largemouth bass	--	--	--	--	--	--	0.10 (1)

Notes:
1. No attempts to collect fish were made in January or July 1994.
2. With the exception of turtles, all analysis was performed on whole body, homogenized samples; all fish of each particular species were combined during homogenization.
3. Analytical results are presented on a wet weight basis.

concentrations of mercury have been higher in Site 8 *Gambusia* than bluegill in every quarter when both species were captured. In January 1993, mercury concentrations in Site 8 *Gambusia* were more than seven times mercury concentrations in bluegill (0.15 mg/kg of mercury in *Gambusia* versus 0.02 mg/kg in bluegill). In October 1994, mercury concentrations in *Gambusia* were nearly four times mercury concentrations in bluegill (0.27 mg/kg of mercury in *Gambusia* versus 0.07 mg/kg in bluegill). *Gambusia* were not collected at either of the two control sites. Therefore, inferences about differential uptake or bioaccumulation of mercury by blue gill and *Gambusia* at these locations cannot be drawn. However, piscivorous predators (e.g., largemouth bass and warmouth) at both control sites tended to show higher levels of mercury in tissues than prey species, such as Notopids/spottail shiner, that feed lower in the food chain on insects and plant material.

The tissue concentrations of mercury measured in the samples of Site 8 bluegill collected in January, April, and July 1993 (0.02, 0.06, and 0.09 mg/kg of mercury, respectively) and April 1994 and October 1994 (0.07 mg/kg of mercury in both instances) were similar to concentrations reported by the USFWS for this area between 1987 and 1990 (USFWS, 1991). Tissue concentrations in Mattawoman Creek bluegill ranged from 0.02 to 0.11 mg/kg over the course of the USFWS study (USFWS, 1991). As noted in these USFWS reports, the levels of mercury reported for Indian Head bluegill are similar to those reported for bluegill collected from other locations in Maryland and the United States. The combined bluegill data (1987 through 1994) suggest that the levels of mercury available to these organisms have remained relatively constant over the last 7 years, and that mercury tissue levels in bluegill have remained within the range reported for this species from other Maryland locations.

Mercury concentrations in brown bullhead from the Site 8 pond ranged from 0.04 mg/kg to 0.06 mg/kg over the course of this investigation (see Table 3-4). Brown bullheads collected in 1985 from Mattawoman Creek in the vicinity of Indian Head NSCW (Marsh Island) averaged 0.04 ppm (mg/kg) wet weight (USFWS, 1990). Brown bullheads collected from 1977 to 1985 by the Maryland Department of Environment from non-tidal Maryland rivers contained an average of 0.064 mg/kg of mercury (Maryland Department of Natural Resources, 1994), while brown bullheads collected in 1989 from Deep Creek Lake (a reservoir in rural western Maryland with a forested watershed) contained 0.037 mg/kg of mercury (Maryland Department of Natural Resources, 1994).

A number of investigators have commented on the tendency of mercury to show higher concentrations in fish in spring than in fall (Maryland Department of Natural Resources, 1994). This has been attributed to increased feeding in the spring, which follows a period of inactivity and much-reduced feeding in the winter. Similarly, food consumption slows in the fall as water temperatures drop and metabolic rates slow. No such

seasonal pattern in mercury levels was observed in this study, although sample sizes were probably too small to detect this kind of subtle variation.

Eisler (1987) suggested that fish tissue levels of 0.1 mg/kg of mercury (wet weight) be used as a guideline for the protection of piscivorous birds (e.g., the common merganser, *Mergus merganser*), and recommended that 1.1 mg/kg of mercury serve as a guidance level for the intake of fish by piscivorous mammals (e.g., the river otter, *Lutra canadensis*). Prior to July 1993, only one Site 8 sample (*Gambusia*, in January 1993) exceeded the 0.1 mg/kg of mercury guidance level, indicating that piscivorous birds and mammals that feed in this area are not at risk.

In July 1993, a warmouth sample from Site 8 showed a mercury level of 0.23 mg/kg. A redfin pickerel from Control Site 1 also contained more than 0.2 mg/kg of mercury in July 1993. These slightly elevated mercury concentrations are not surprising given the food habits of these species. Warmouth have a more piscivorous diet than most Lepomids (or "sunfish"), which is generally attributed to the warmouth's large, bass-like mouth (Carlander, 1977). Redfin pickerel are also carnivores, eating insects, crayfish, and fish, but are increasingly piscivorous as they attain larger sizes (Carlander, 1969; Lee et al., 1980). Piscivorous species such as the warmouth and redfin pickerel that feed high in the food chain tend to bioaccumulate mercury (Sorensen, 1991).

After July 1993, only one species collected at Site 8, the eastern mosquitofish (*Gambusia*), contained tissue concentrations of mercury higher than the suggested 0.1 mg/kg Hg guideline. In October 1993, a composite sample (36 fish) of *Gambusia* from Site 8 contained 0.12 mg/kg of mercury. As noted earlier, a composite sample (75 fish) of *Gambusia* from the Site 8 pond in October 1994 contained 0.27 mg/kg of mercury. This tendency of Site 8 *Gambusia* to accumulate relatively-high concentrations of mercury is difficult to explain. In the absence of detailed information on the sex, reproductive condition (mature versus immature, spawning versus non-spawning) age, health, and gut contents of *Gambusia* in Site 8 samples, it would be pointless to speculate on possible reasons for these elevated mercury levels.

Irwin (1988) noted that *Gambusia affinis*, a species closely related to *Gambusia holbrooki* (and once thought to be the same species), is a hardy, pollution-tolerant species that often contains elevated body burdens of "certain (toxic) chemicals." Irwin found 0.01 to 0.23 mg/kg of mercury in composite samples of *Gambusia* from the Trinity River (Texas), with the highest concentrations occurring just downstream of the city of Dallas.

The highest concentrations of mercury measured over the course of this investigation were both observed in fish from control sites. In April 1994, a pumpkinseed sample from Control Site 2 (Mattawoman Creek)

contained 0.29 mg/kg of mercury. In October 1994, a largemouth bass sample from Control Site 1 contained 0.29 mg/kg or mercury.

It should be noted that four of the five samples collected over the course of this investigation with mercury concentrations higher than 0.2 mg/kg consisted of a single fish (see Table 3-4). The pitfalls of drawing inferences from a single observation are obvious. Mercury is notorious for accumulating in fish muscle and viscera at radically different rates, even within a population. This variability in rate of mercury accumulation has been attributed to genetic differences between fish, differences in sex and maturity, size-related differences, and the presence or absence of pesticides, organic wastes, and other chemical agents (Sorensen, 1991). The elevated concentrations of mercury in the redfin pickerel and largemouth bass from Control Site 1 and the warmouth from Site 8 and Control Site 2 appear to be related to the tendency of carnivorous fish species to bioaccumulate mercury (whether the source be industrial, atmospheric, or geologic) rather than the presence of high levels of mercury in the water, sediment, or biota of either pond. The elevated levels of mercury in Site 8 *Gambusia* are more puzzling, given this species' food habits (i.e., omnivorous, feeding on plant material, plankton, and insects) and habitat preferences (i.e., a surface feeder, spending very little time in the vicinity of contaminated bottom sediments).

Supplemental samples of frogs collected from the Site 8 pond in April 1993 and crayfish collected in July 1993 contained 0.03 and 0.07 mg/kg of mercury, respectively. A composite sample of four crayfish collected in October 1993 contained 0.09 mg/kg. As noted previously, Eisler (1987) suggests that for the protection of sensitive species of birds and mammals that "regularly consume fish and other aquatic organisms," that total mercury concentrations in the prey items should not exceed 0.1 mg/kg wet weight for birds and 1.1 mg/kg for mammals. Thus, the mercury concentrations measured in crayfish and frogs from Site 8 do not appear to represent a hazard to animals (such as wading birds and raccoons) that feed on them.

Mercury concentrations in livers of painted turtles collected at Site 8 in April 1994 averaged 1.3 mg/kg. In October, mercury concentrations in painted turtle livers averaged 0.35 mg/kg, while mercury concentrations in turtle muscle tissue were considerably lower, averaging 0.07 mg/kg. Because very little information exists on background levels of mercury in turtles, interpreting these results is difficult. Eisler's (1987) review contains data on mercury levels in field collections of frogs, toads, and sea turtle eggs, but contains no information on mercury concentrations in tissues of aquatic and semi-aquatic freshwater turtles. Note that no fish were collected in July, and as a result no turtles were collected.

Whole body mercury concentrations of 0.05 to 0.06 mg/kg were found in softshell turtles (*Trionyx* sp.) collected from comparatively-rural and presumably uncontaminated sections of the Trinity River in Texas

(Irwin, 1988). A composite whole-body sample of softshell turtles collected from the Rio Grande River at Big Bend National Park had a mercury concentration of 0.073 mg/kg (Irwin, 1989). Concentrations of 0.18 mg/kg Hg were found in whole-body samples of softshell turtles from two highly-polluted Trinity River (Texas) sites (Irwin, 1988). The highest concentration of mercury (0.85 mg/kg) observed in the USFWS Trinity River study was found in a composite sample of fat dissected from three Mississippi map turtles (*Graptemys kohni*).

Mercury concentrations in kidney and muscle tissues of pond sliders (*Trachemys scripta*) and snapping turtles (*Chelydra serpentina*) from Bearden Creek Embayment, which is used as an uncontaminated reference site by the Oak Ridge National Laboratory, had mean kidney and muscle concentrations of 0.12 and 0.03 mg/kg Hg (pond sliders) and 0.34 and 0.10 mg/kg Hg (snapping turtles), respectively (Meyers-Schone et al., 1993).

Frogs from a Florida lake had 0.5 to 1.1 mg/kg of mercury in liver tissue (Eisler, 1987). Toads from an unpolluted area in Yugoslavia had liver mercury concentrations of 1.5 mg/kg, while those from polluted mining areas had 21.8 to 25.5 mg/kg (Eisler, 1987). Based on Eisler (1987), mercury concentration in amphibians (frogs and toads), fish, birds, and mammals are typically 2 to 10 times higher in liver tissue than in muscle tissue.

The April 1994 biomonitoring results suggested that painted turtles at Site 8 contained elevated mercury levels, but were somewhat ambiguous because only liver samples were analyzed. Turtle livers were collected and analyzed because of the known tendency of mercury to concentrate in liver tissue. In October, however, mercury concentrations in the turtle liver and muscle tissue appeared to be within a normal range. But caution should be employed in interpreting these results because of the small sample sizes and the fact that the literature contains limited information on normal background levels of mercury in semi-aquatic turtles. It would be necessary to collect many more turtles and analyze mercury levels in muscle, kidney, liver, and bony (either long bones or shell) tissue to produce definitive results, however.

Composite fish and individual turtle samples from the April and October 1994 rounds of biomonitoring were split and analyzed for both mercury and lead residues. Results of lead analyses are presented in Table 3-5. No clear-cut patterns of lead contamination or lead accumulation in fish have emerged from these preliminary investigations. In April 1994, no fish from the Site 8 pond contained measurable levels of lead, whereas fish from both control sites contained measurable levels. Although bottom-feeding and bottom-dwelling species are more likely to accumulate significant body burdens of lead as a result of lead's tendency to bind to bottom sediment (Van Hassel et al., 1980; Eisler, 1988), no such pattern was observed in April 1994. Sample sizes were probably too small to detect any such tendencies, however. A sample

TABLE 3-5

LEAD CONCENTRATIONS IN FISH AND TURTLES
APRIL AND OCTOBER 1994
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Organism	Lead Concentration in mg/kg (sample size)					
	Site 8		Control Site 1 (Stump Neck Beaver Pond)		Control Site 2 (Mattawoman Creek)	
	April	October	April	October	April	October
Common carp	<0.2[a] (2)	---	---	---	---	---
Gambusia	---	0.2 (75)	---	---	---	---
Notropis sp.	---	---	0.3 (4)	0.4 (2)	---	---
Spottail shiner	---	---	---	---	IS (1)	---
Cheek chubsucker	---	---	IS (1)	ND (2)	---	ND (3)
Brown bullhead	---	0.5 (2)	---	---	0.3 (1)	<0.2[a] (2)
Pumpkinseed	ND (3)	---	<0.2 (1)	---	0.3 (1)	---
Warmouth	---	---	---	---	---	ND (1)
Bluegill	<0.2[a](3)	ND (4)	---	---	ND (6)	ND (3)
Largemouth bass	---	---	---	<0.2 [a] (1)	---	ND (1)
White crappie	---	ND (2)	---	---	---	---
Turtle (liver)	0.5 (2)	<0.3[b] (2)	---	---	---	---
Turtle (muscle)	not sampled	<0.3[b] (2)	---	---	---	---

IS - Insufficient sample volume for analysis.
ND - Value is nondetected as reported by laboratory: 0.2 mg/kg (ppm) is lower level of quantification.
a - Detected, but below measurable quantity.
b - One sample contained 0.3 mg/kg Pb; one sample did not contain detectable quantity.

of carp (two small fish) from the Site 8 pond in April 1994 contained low, but detectable (< 0.2 mg/kg) concentrations of lead. A brown bullhead sample (one small fish) from the Mattawoman Creek control site contained a low, but measurable (0.3 mg/kg) concentration of lead. Both species are omnivorous bottom feeders (Scott and Crossman, 1973).

Notropid (unidentified shiners) minnows from the beaver pond control site also contained low, but measurable, concentrations of lead in April 1994 as did a pumpkinseed (one fish) from Mattawoman Creek. Notropid food habits vary with the species and the size/age of individual fish. Notropids feed on plant material, plankton, and both larval and adult insects (Tomelleri and Eberle, 1990). Some species feed on the bottom, while others feed primarily at the surface (Scott and Crossman, 1973). Pumpkinseed are opportunistic omnivores that feed at the surface, at various depths in the water column, and at the bottom (Scott and Crossman, 1973).

Lead levels in October 1994 fish samples from the Site 8 pond were generally low. One species, brown bullhead, contained lead concentrations that appear to be higher than background levels. Lead concentrations in three other fish species were at or below the analytical quantitation limit for lead of 0.2 mg/kg. Measurable concentrations (0.4 mg/kg) of lead were also present in Notropid (shiner) minnows from Control Site 1 (Stump Neck beaver pond).

Data from the State of Maryland's Basic Water Monitoring Program (Maryland Department of the Environment, 1988) suggest that lead levels in fish from Site 8 are typically lower than those observed in streams and rivers elsewhere in Maryland. Brown bullhead from the Lower Potomac River contained an average of 2.9 ppm lead in 1985, while brown bullhead from the Patuxent River contained 2.1 ppm lead. Bluegill from the Patuxent River contained 2.2 ppm of lead in 1985. Pumpkinseed from the Choptank River contained 3.1 ppm of lead in 1985. Redbreast collected in 1985 contained 2.6 ppm lead (Gunpowder River), 2.1 ppm lead (Patapsco River), 0.9 ppm lead (Lower Potomac River), and 2.0 ppm lead (Middle Potomac River). Fish from virtually every stream in Maryland sampled in 1985 contained higher levels of lead than fish in the Site 8 pond.

The fact that lead concentrations are elevated in Site 8 sediments and relatively low in Site 8 fish is not unusual, given lead's tendency to bind to sediments. Numerous studies have shown that lead in sediments is not readily bioavailable (Getz et al., 1977; Wiener and Giesy, 1979; Johnson, 1987). In a comprehensive study of lead dynamics in an Illinois watershed, Getz et al. (1977) found concentrations of lead in stream sediments that were two (a hundred times) to six orders of magnitude (a million times) higher than concentrations in benthic macroinvertebrates and fish. Demayo et al. (1982) found sediment concentrations

of lead in an Oklahoma pond from 206 to 529 ppm, while *Gambusia* from the same pond contained 11 ppm of lead.

Unlike mercury, lead does not biomagnify (Eisler, 1988). Lead concentrations in aquatic ecosystems are often higher in sediments than in benthic macroinvertebrates, and higher in benthic macroinvertebrates than in surface-feeding or pelagic fish (Van Hassel et al., 1980; Eisler, 1988). Getz et al. (1977) noted that lead concentrations in aquatic organisms appear to be influenced by the amount of contact an organism has with contaminated sediments. Lead tends to concentrate in the bony tissues of individual fish, particularly species that forage on the bottom, and to accumulate in these tissues over time. Thus, older individuals may be at risk in a contaminated stream or lake, and in particular bottom-feeding groups such as bullheads, carpsuckers, and redhorse.

In April 1994, lead concentrations in liver tissue from two painted turtles from the Site 8 pond averaged 0.5 mg/kg. In October 1994, liver and muscle tissue from one turtle contained a measurable concentration of lead (0.3 mg/kg), while liver and muscle tissue from another turtle did not contain a detectable quantity. Because almost no information on lead residues in reptiles is available, the significance of this data is difficult to assess. Eisler (1988) lists only one investigation of lead levels in turtles, but the species studied (the eastern box turtle, *Terrapene carolina*), is a largely terrestrial species, while the painted turtle is semi-aquatic. Perhaps more importantly, in terms of comparing body burdens of metals, the eastern box turtle is an unusually long-lived turtle species: 30- to 40-year-old individuals are common, and they may live as long as 100 years (Conant, 1975). Lead concentrations in a 17-year-old box turtle from an uncontaminated site in West Virginia were 4.0 mg/kg (long bones), 2.0 mg/kg (kidney), 1.0 mg/kg (liver), and 0.1 mg/kg (skin) (Eisler, 1988). Based on this study (and other studies of snakes, frogs, and toads in the same reference), the lead concentration in livers of painted turtles from Site 8 appear to be unremarkable.

These limited data provide no evidence that lead contamination at Site 8 has moved into the food chain to a significant extent. Sorensen (1991) presents evidence for a variety of subtle, non-lethal effects of low levels of lead, among them hematological changes, respiratory changes, neuromuscular abnormalities, behavioral changes, and growth inhibition, but generally at concentrations higher than those observed at Site 8 in this study. In order to definitively rule out these kinds of subtle effects, however, it would be necessary to collect more fish from Site 8 for analyses of lead in tissues and histopathological studies. Older fish and bottom-dwelling species would be preferred, because research has shown that older, larger fish tend to contain higher body burdens of lead than younger, smaller fish (Eisler, 1988).

4.0 SUMMARY AND CONCLUSIONS

4.1 SUMMARY

4.1.1 Periphyton

The periphyton community of Site 8 was dominated by diatoms and green algae in October 1992 and July 1993, and by diatoms in January and April 1993. In October 1993 and January 1994, the periphyton community showed more variety, with diatoms, green algae, blue-green algae, and golden-brown algae all present in large numbers. In April 1994, the periphyton community was composed mostly of diatoms, green algae, and blue-green algae. In July 1994, periphyton were numerically dominated by blue-green algae, but most of the periphyton biomass was made up of diatoms. In October 1994 and February 1995, diatoms and green algae were numerically dominant, but significant numbers of blue-green algae and golden-brown algae were also present. Periphyton, which are short-lived and very prolific, often show in these kinds of pronounced seasonal shifts in community structure.

4.1.2 Benthic Macroinvertebrates

The Site 8 benthic macroinvertebrate community is composed largely of herbivores that feed on attached algae (e.g., chironomids) and detritivores that feed on organic detritus (e.g., oligochaetes). There has been very little change in benthic community structure since April 1993. The simple structure and low diversity of the Site 8 benthic community are typical of tidal freshwater marshes and ponds of the east coast with their featureless sand and mud substrates.

4.1.3 Fish

The two most abundant fish species in 1992 collections from the Site 8 pond were mosquitofish (*Gambusia*) and mummichog, omnivores that feed on plant matter, larval and adult insects, and small fish. In 1993, no species of fish was abundant, but bluegill, brown bullhead, mosquitofish, and mummichog were all collected on two or more occasions. In 1994, fish collections were dominated by *Gambusia* and centrarchids (sunfish and crappie), but small numbers of common carp and brown bullhead were also collected. Fish species richness and abundance are low at Site 8.

Concentrations of mercury in fish tissue from Site 8 over the course of this investigation have revealed no clear differences between species (with the exception of *Gambusia*, which appear to accumulate mercury to a certain extent) or areas (between Site 8 and the two control sites). Limited investigations of lead residues in fish from Site 8 have shown no evidence that lead in sediments has moved into the food chain to a significant degree.

Mercury levels in fish samples collected in the first five quarters of biomonitoring (October 1992 through October 1993) were generally below those suggested as a guideline for protection of sensitive piscivorous birds (0.1 mg/kg) and piscivorous mammals (1.1 mg/kg). There were exceptions, however. In July 1993, a warmouth from the Site 8 pond and a redfin pickerel from Control Site 1 contained 0.23 and 0.21 mg/kg of mercury, respectively. In October 1993, one species from Site 8 (mosquitofish) and two species from Control Site 1 (creek chub and pumpkinseed) contained mercury levels >0.1 mg/kg.

In April 1994, no Site 8 fish contained mercury concentrations higher than 0.09 mg/kg, but a pumpkinseed collected from the Mattawoman Creek Control Site contained 0.29 mg/kg of mercury, the highest concentration measured at this location over the course of the study. In October 1994, a sample of *Gambusia* from the Site 8 pond contained 0.27 mg/kg of mercury, but three other species contained low levels of mercury. A largemouth bass sample from Control Site 1 in October 1994 contained 0.29 mg/kg or mercury. All indications are that mercury levels in Site 8 biota have stabilized, that these levels are generally low, and that birds and mammals that feed on Site 8 fish and invertebrates are not at risk from mercury contamination.

4.1.4 Supplemental Sediment Sampling and Analysis at Site 8

Results of supplemental sediment sampling conducted in May 1994 at Site 8 indicate that there are elevated levels of lead in the sediments downstream of NPDES discharge point IW-31. The lowest concentration of lead was found in the sediments upstream of the NPDES discharge point. All downstream sampling locations contained higher levels of lead. Lead levels in Site 8 pond sediments are generally two orders of magnitude higher than background levels (i.e., upstream of the NPDES outfall).

4.1.5 Supplemental Sediment Sampling and Analysis at Control Site 1

Results of supplemental sediment sampling conducted at Control Site 1 (Stump Neck Beaver Pond) indicate that Control Site 1 is not contaminated with mercury. This supplemental sampling was conducted to confirm the suitability of the Stump Neck pond as a control site.

4.2 CONCLUSIONS

4.2.1 Mercury

Although mercury levels in sediments of the Site 8 pond are higher than those at the control sites, there does not appear to be a corresponding increase in mercury levels detected in fish and other aquatic organisms at Site 8. Only one fish species, the eastern mosquitofish (*Gambusia holbrooki*), appears to contain tissue concentrations of mercury that are above background, but predatory fish species (e.g., white crappie) in the Site 8 pond that feed on *Gambusia* do not contain elevated levels of mercury. There is no evidence to suggest that fish and wildlife at Site 8 have been significantly affected by mercury contamination.

4.2.2 Lead

Composite samples of fish from the Site 8 pond contained low concentrations of lead in July and October 1994, as did samples of fish from the two control sites. Liver and muscle tissue from painted turtles collected at Site 8 contained concentrations of lead that appear to be within a normal range, based on the limited information in the scientific literature. These data suggest that lead in sediments at Site 8 is in a form that is not readily bioavailable and that Site 8 biota are not accumulating lead to a significant degree.

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APPENDIX A

PERIPHYTON SAMPLING RESULTS

TABLE A-1

TRANSECT 1W
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cyclotella	151	3.1	2.7	1.4
Melosira	301	6.2	9.71	4.9
Navicula	1808	37.5	69.89	35.1
Pinnularia	301	6.2	86.98	43.7
Surirella	452	9.4	18.64	9.4
CHLOROPHYTA				
Chlamydomonas	452	9.4	1.77	0.9
Chlorella	452	9.4	4.91	2.5
Elathothrix	603	12.5	1.05	0.5
CYANOPHYTA				
Chroococcus	301	6.2	3.27	1.6
TOTALS	**4,821**	**100.0**	**198.92**	**100.0**
BACILLARIOPHYTA	3,013	62.5	187.92	94.5
CHLOROPHYTA	1,507	31.3	7.73	3.9
CYANOPHYTA	301	6.2	3.27	1.6

TABLE A-2

TRANSECT 1C
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cyclotella	352	11.6	6.29	6.2
Navicula	1,172	38.5	45.3	44.8
Nitzschia	117	3.8	6.98	6.9
Pinnularia	117	3.8	33.82	33.5
CHLOROPHYTA				
Chlamydomonas	469	15.4	1.83	1.8
Chlorella	586	19.2	6.36	6.3
CHRYSOPHYTA				
Chromulina	117	3.8	0.44	0.4
CYANOPHYTA				
Synechocystis	117	3.8	0.08	0.1
TOTALS	**3,047**	**100.0**	**101.1**	**100.0**
BACILLARIOPHYTA	3,047	100.0	101.1	100.0
CHLOROPHYTA	1,758	57.70	92.39	91.38
CHRYSOPHYTA	1,055	34.62	0.44	0.44
CYANOPHYTA	117	3.84	0.08	0.08

TABLE A-3

TRANSECT 1E
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cyclotella	137	12.5	2.45	7.5
Navicula	411	37.5	15.9	48.7
Surirella	274	25.0	11.31	34.7
CHRYSOPHYTA				
Chlorella	274	25.0	2.98	9.1
TOTALS	**1,096**	**100.0**	**32.64**	**100.0**
BACILLARIOPHYTA	822	75.0	29.66	90.9
CHRYSOPHYTA	274	25.0	2.98	9.1

TABLE A-4

TRANSECT 1 SUMMARY
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Mean Density (cells/cm^2)	Relative Abundance (%)	Mean Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cyclotella	213	7.1	3.81	3.4
Melosira	100	3.4	3.24	2.9
Navicula	1,130	37.8	43.70	39.4
Nitzschia	39	1.3	2.33	2.1
Pinnularia	139	4.7	40.27	36.3
Surirella	242	8.1	9.98	9.0
CHLOROPHYTA				
Chlamydomonas	307	10.3	1.20	1.1
Chlorella	437	14.6	4.75	4.3
Elathothrix	201	6.7	0.35	0.3
CHRYSOPHYTA				
Chromulina	39	1.3	0.15	0.1
CYANOPHYTA				
Chroococcus	100	3.4	1.09	1.0
Synechocystis	39	1.3	0.03	0.0
TOTALS	**2,988**	**100.0**	**111.0**	**100.0**
BACILLARIOPHYTA	1,864	62.4	103.0	93.2
CHLOROPHYTA	945	31.6	6.0	5.7
CHRYSOPHYTA	39	1.3	0.0	0.1
CYANOPHYTA	139	4.7	1.0	1.0

TABLE A-5

TRANSECT 2W
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Mean Density (cells/cm^2)	Relative Abundance (%)	Mean Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cyclotella	12,395	28.3	221.78	12.9
Gomophonema	791	1.8	1.97	0.1
Navicula	4,483	10.2	173.27	10.1
Pinnularia	527	1.2	152.21	8.8
Stephanodiscus	1,319	3.0	414.69	24.1
Surirella	11,868	27.1	489.25	28.4
Synedra	1,319	3.0	110.37	6.4
CHLOROPHYTA				
Chlamydomonas	1,846	4.2	7.22	0.4
Chlorella	3,429	7.8	37.23	2.2
Scenedesmus	1,055	2.4	2.29	0.1
CHRYSOPHYTA				
Chromulina	527	1.2	1.96	0.1
CYANOPHYTA				
Dactylococcopsis	264	0.6	0.14	0.0
Oscillatoria	3,956	9.0	111.2	6.5
TOTALS	**43,779**	**100.0**	**1,723.58**	**100.0**
BACILLARIOPHYTA	32,702	74.70	1,563.54	90.71
CHLOROPHYTA	6,330	14.46	46.74	2.71
CHRYSOPHYTA	527	1.20	1.96	0.11
CYANOPHYTA	4,220	9.64	111.34	6.46

TABLE A-6

TRANSECT 2C
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Achnanthes	1,076	2.8	39.43	2.9
Cocconeis	359	0.9	14.79	1.1
Cyclotella	13,630	35.8	243.87	18.1
Cymbella	359	0.9	30.03	2.2
Eunotia	359	0.9	26.29	2.0
Navicula	7,891	20.8	304.96	22.7
Stauroneis	359	0.9	56.47	4.2
Surirella	5,021	13.2	207.01	15.4
Synedra	4,663	12.3	390.25	29.0
CHLOROPHYTA				
Chlamydomonas	359	0.9	1.4	0.1
Chlorella	2,152	5.7	23.37	1.7
Ulothrix	1,435	3.8	5.88	0.4
CHRYSOPHYTA				
Chromulina	359	0.9	1.34	0.1
TOTALS	**38,022**	**100.0**	**1,345.09**	**100.0**
BACILLARIOPHYTA	33,717	88.7	1,313.1	97.6
CHLOROPHYTA	3,946	10.4	30.65	2.3
CHRYSOPHYTA	359	0.9	1.34	0.1

TABLE A-7

TRANSECT 2E
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Achnanthes	1,407	6.6	51.54	4.3
Cyclotella	3,938	18.4	70.47	5.8
Navicula	5,064	23.7	195.7	16.2
Pinnularia	563	2.6	162.36	13.4
Stauroneis	281	1.3	44.29	3.7
Stephanodiscus	1,125	5.3	353.87	29.3
Surirella	5,345	25.0	220.34	18.2
Synedra	1,125	5.3	94.18	7.8
CHLOROPHYTA				
Chlorella	844	3.9	9.16	0.8
Oocystis	563	2.6	6.11	0.5
CYANOPHYTA				
Stichosiphon	1,125	5.3	1.53	0.1
TOTALS	**21,380**	**100.0**	**1,209.55**	**100.0**
BACILLARIOPHYTA	18,848	88.2	1,192.75	98.6
CHLOROPHYTA	1,407	6.6	15.27	1.3
CYANOPHYTA	1,125	5.3	1.53	0.1

TABLE A-8

TRANSECT 2 SUMMARY
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Mean Density (cells/cm^2)	Relative Abundance (%)	Mean Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Achnanthes	828	2.4	30.32	2.1
Cocconeis	120	0.3	4.93	0.3
Cyclotella	9,988	29.0	178.71	12.5
Cymbella	120	0.3	10.01	0.7
Eunotia	120	0.3	8.76	0.6
Gomphonema	264	0.8	0.66	0.0
Navicula	5,813	16.9	224.64	15.8
Pinnularia	363	1.1	104.86	7.4
Stauroneis	213	0.6	33.59	2.4
Stephanodiscus	815	2.4	256.19	18.0
Surirella	7,411	21.5	305.53	21.4
Synedra	2,369	6.9	198.27	13.9
CHLOROPHYTA				
Chlamydomonas	735	2.1	2.87	0.2
Chlorella	2,142	6.2	23.25	1.6
Oocystis	188	0.5	2.04	0.1
Scenedesmus	352	1.0	0.76	0.1
Ulothrix	478	1.4	1.96	0.1
CHRYSOPHYTA				
Chromulina	295	0.9	1.10	0.1
CYANOPHYTA				
Dactylococcopsis	88	0.3	0.05	0.0
Oscillatoria	1,319	3.8	37.07	2.6
Stichosiphon	375	1.1	0.51	0.0
TOTALS	**34,394**	**100.0**	**1,426.0**	**100.0**
BACILLARIOPHYTA	28,422	83.0	1,356.0	95.0
CHLOROPHYTA	3,894	11.32	31.0	2.17
CHRYSOPHYTA	295	0.86	1.0	0.08
CYANOPHYTA	1,782	5.18	38.0	2.64

TABLE A-9

TRANSECT 3W
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cymbella	738	3.4	61.84	8.6
Melosira	3,446	15.7	110.99	15.5
Navicula	2,461	11.2	95.13	13.3
Stephanodiscus	246	1.1	77.41	10.8
Surirella	6,154	28.1	253.68	35.4
Synedra	738	3.4	61.81	8.6
CHLOROPHYTA				
Chlamydomonas	2,461	11.2	9.62	1.3
Chlorella	1,969	9.0	21.38	3.0
CHRYSOPHYTA				
Chromulina	246	1.1	0.92	0.1
CYANOPHYTA				
Gloeocapsa	1,969	9.0	1.37	0.2
unident.blue green	246	1.1	2.56	0.4
CYRPTOPHYTA				
Cryptomonas	738	3.4	4.62	0.6
EUGLENOPHYTA				
Euglena	492	2.2	16.04	2.2
TOTALS	**21,904**	**100.0**	**717.37**	**100.0**
BACILLARIOPHYTA	13,783	62.9	660.86	92.1
CHLOROPHYTA	4,430	20.2	31.0	4.3
CHRYSOPHYTA	246	1.1	0.92	0.1
CYANOPHYTA	2,215	10.1	3.93	0.5
CRYPTOPHYTA	738	3.4	4.62	0.6
EUGLENOPHYTA	492	2.2	16.04	2.2

TABLE A-10

TRANSECT 3C
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Achnanthes	914	12.9	33.5	10.1
Cyclotella	229	3.2	4.09	1.2
Euontia	229	3.2	16.75	5.0
Navicula	2,057	29.0	79.5	23.9
Stauroneis	457	6.4	71.98	21.7
Surirella	2,514	35.5	103.65	31.2
Synedra	229	3.2	19.13	5.8
CHLOROPHYTA				
Chlamydomonas	229	3.2	0.89	0.3
Chlorella	229	3.2	2.48	0.7
TOTALS	**7,087**	**100.0**	**331.97**	**100.0**
BACILLARIOPHYTA	6,629	93.5	328.6	99.0
CHLOROPHYTA	458	6.5	3.37	1.0

TABLE A-11

TRANSECT 3E
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cyclotella	2,637	12.8	28.31	8.9
Navicula	527	2.6	24.46	7.7
Surirella	3,692	17.9	113.55	35.6
CHLOROPHYTA				
Chlamydomonas	3,165	15.4	12.37	3.9
Chlorella	3,692	17.9	40.09	12.6
Chlorogonium	527	2.6	9.28	2.9
Oedogonium	3,165	15.4	35.17	11.0
Ulothrix	2,110	10.3	8.65	2.7
PYRROPHYTA				
Peridinium	1,055	5.1	46.92	14.7
TOTALS	**20,570**	**100.0**	**318.8**	**100.0**
BACILLARIOPHYTA	6,856	33.3	166.32	52.2
CHLOROPHYTA	12,659	61.5	105.56	33.1
PYRROPHYTA	1,055	5.1	46.92	14.7

TABLE A-12

TRANSECT 3 SUMMARY
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Mean Density (cells/cm^2)	Relative Abundance (%)	Mean Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Achnanthes	305	1.8	11.17	2.2
Cyclotella	955	5.8	10.80	2.1
Cymbella	246	1.5	20.61	4.0
Euontia	76	0.5	5.58	1.1
Melosira	1,149	7.0	37.00	7.3
Navicula	1,682	10.2	66.36	13.0
Stauroneis	152	0.9	23.99	4.7
Stephanodiscus	82	0.5	25.80	5.1
Surirella	4,120	24.9	156.96	30.8
Synedra	322	2.0	80.94	15.9
CHLOROPHYTA				
Chlamydomonas	1,952	11.8	7.63	1.5
Chlorella	1,963	11.9	21.32	4.2
Chlorogonium	176	1.1	3.09	0.6
Oedogonium	1,055	6.4	11.72	2.3
Ulothrix	703	4.3	2.88	0.6
CHRYSOPHYTA				
Chromulina	82	0.5	0.31	0.1
CYANOPHYTA				
Gloeocapsa	656	4.0	0.46	0.1
unident.blue green	82	0.5	0.85	0.2
CRYPTOPHYTA				
Cryptomonas	246	1.5	1.54	0.3
EUGLENOPHYTA				
Euglena	164	1.0	5.35	1.0

TABLE A-12 (Continued)
TRANSECT 3 SUMMARY
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND
February 1995

Taxon	Mean Density (cells/cm^2)	Relative Abundance (%)	Mean Weight (mg/m^2)	Relative Weight (%)
PYRROPHYTA				
Peridinium	352	2.1	15.64	3.1
TOTALS	**16,520**	**100.0**	**510.01**	**100.0**
BACILLARIOPHYTA	9,089	55.0	439.22	86.1
CHLOROPHYTA	5,849	35.4	46.64	9.1
CHRYSOPHYTA	82	0.5	0.31	0.1
CYANOPHYTA	738	4.5	1.31	0.3
CRYPTOPHYTA	246	1.5	1.54	0.3
EUGLENOPHYTA	164	1.0	5.35	1.0
PYRROPHYTA	352	2.1	15.64	3.1

TABLE A-13

TRANSECT 4W
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cyclotella	277	2.6	4.95	3.6
Navicula	1,662	15.4	64.21	46.1
Synedra	277	2.6	23.18	16.6
CHLOROPHYTA				
Chlorella	831	7.7	9.02	6.5
CYANOPHYTA				
Dactylococcopsis	277	2.6	0.15	0.1
Dermocarpa	3,877	35.9	9.09	6.5
Stichosiphon	3,046	28.2	4.13	3.0
PYRROPHYTA				
Peridinium	554	5.1	24.63	17.7
TOTALS	**10,801**	**100.0**	**139.36**	**100.0**
BACILLARIOPHYTA	2,216	20.5	92.34	66.3
CHLOROPHYTA	831	7.7	9.02	6.5
CYANOPHYTA	7,200	66.7	13.37	9.6
PYRROPHYTA	554	5.1	24.63	17.7

TABLE A-14

TRANSECT 4C
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cyclotella	831	1.9	14.86	4.1
Melosira	415	0.9	13.38	3.6
Surirella	4,154	9.4	171.24	46.7
Synedra	415	0.9	34.77	9.5
CHRYSOPHYTA				
Chromulina	1,662	3.8	6.19	1.7
CHLOROPHYTA				
Chlamydomonas	2,077	4.7	8.12	2.2
Chlorella	4,985	11.3	54.13	14.8
Chlorogonium	7,061	16.0	62.24	17.0
CYANOPHYTA				
unidentified blue-green fil.	22,430	50.9	1.95	0.5
TOTALS	**44,030**	**100.0**	**366.88**	**100.0**
BACILLARIOPHYTA	5,815	13.2	234.25	63.8
CHRYSOPHYTA	1,662	3.8	6.19	1.7
CHLOROPHYTA	14,123	32.1	124.49	33.9
CYANOPHYTA	22,430	50.9	1.95	0.5

TABLE A-15

TRANSECT 4E
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cyclotella	352	11.8	6.29	10.6
Gomphonema	176	5.9	0.44	0.7
Melosira	703	23.5	22.65	38.3
Navicula	176	5.9	6.8	11.5
Surirella	352	11.8	14.5	24.5
CHLOROPHYTA				
Chlamydomonas	703	23.5	2.75	4.6
Chlorella	527	17.6	5.73	9.7
TOTALS	**2,989**	**100.0**	**59.16**	**100.0**
BACILLARIOPHYTA	1,759	58.8	50.68	85.7
CHLOROPHYTA	1,230	41.2	8.48	14.3

TABLE A-16

TRANSECT 4 SUMMARY
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Mean Density (cells/cm^2)	Relative Abundance (%)	Mean Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cyclotella	487	2.5	8.70	4.6
Gomphonema	59	0.3	0.15	0.1
Melosira	373	1.9	12.01	6.4
Navicula	613	3.2	23.67	12.6
Surirella	1,502	7.8	61.91	32.9
Synedra	231	1.2	19.32	10.2
CHLOROPHYTA				
Chlamydomonas	927	4.8	3.62	1.9
Chlorella	2,114	11.0	22.96	12.2
Chlorogonium	2,354	12.2	20.75	11.0
CYRYSOPHYTA				
Chromulina	554	2.9	2.06	1.1
CYANOPHYTA				
Dactylococcopsis	92	0.5	0.05	0.0
Dermocarpa	1,292	6.7	3.03	1.6
Stichosiphon	1,015	5.3	1.38	0.7
unident.blue-green fil.	7,477	38.8	0.65	0.3
PYRROPHYTA				
Peridinium	185	1.0	8.21	4.4
TOTALS	**19,273**	**100.0**	**188.47**	**100.0**
BACILLARIOPHYTA	3,263	16.9	125.76	66.7
CHLOROPHYTA	5,395	28.0	47.33	25.1
CHRYSOPHYTA	554	2.9	2.06	1.1
CYANOPHYTA	9,877	51.2	5.11	2.7
PYRROPHYTA	185	1.0	8.21	4.4

TABLE A-17

CONTROL SITE 1 (BEAVER POND TRANSECT W)
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cyclotella	14,118	69.5	252.61	46.9
Eunotia	193	1.0	14.17	2.6
Navicula	967	4.8	37.37	6.9
Surirella	3,094	15.2	127.57	23.7
Synedra	1,160	5.7	97.12	18.0
CHLOROPHYTA				
Chlorella	580	2.9	6.3	1.2
Chlorogonium	193	1.0	3.4	0.6
TOTALS	**20,305**	**100.0**	**538.54**	**100.0**
BACILLARIOPHYTA	19,532	96.2	528.84	98.2
CHLOROPHYTA	773	3.8	9.7	1.8

TABLE A-18

CONTROL SITE 1 (BEAVER POND TRANSECT C)
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cyclotella	4,708	42.4	84.23	21.7
Melosira	336	3.0	10.83	2.8
Navicula	1,681	15.1	64.98	16.8
Stauroneis	336	3.0	52.95	13.7
Surirella	2,690	24.2	110.9	28.6
Synedra	673	6.1	56.29	14.5
CHLOROPHYTA				
Chlorella	673	6.1	7.3	1.9
TOTALS	**11,097**	**100.0**	**387.48**	**100.0**
BACILLARIOPHYTA	10,424	93.9	380.18	98.1
CHLOROPHYTA	673	6.1	7.3	1.9

TABLE A-19

CONTROL SITE 1 (BEAVER POND TRANSECT E)
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cocconeis	422	4.2	17.4	5.4
Cyclotella	5,275	52.1	94.38	29.1
Cymbella	633	6.3	53.0	16.3
Melosira	422	4.2	13.59	4.2
Navicula	211	2.1	8.15	2.5
Surirella	1,899	18.8	78.28	24.1
Synedra	633	6.3	52.98	16.3
CHLOROPHYTA				
Chlorella	633	6.3	6.87	2.1
TOTALS	**10,128**	**100.0**	**324.65**	**100.0**
BACILLARIOPHYTA	9,495	93.8	317.78	97.9
CHLOROPHYTA	633	6.3	6.87	2.1

TABLE A-20

CONTROL SITE 1 (BEAVER POND TRANSECT) SUMMARY
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Mean Density (cells/cm^2)	Relative Abundance (%)	Mean Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cocconeis	141	1.0	5.80	1.4
Cyclotella	8,034	58.0	143.74	34.5
Cymbella	211	1.5	17.67	4.2
Eunotia	64	0.5	4.72	1.1
Melosira	253	1.8	8.14	2.0
Navicula	953	6.9	36.83	8.8
Stauroneis	112	0.8	17.65	4.2
Surirella	2,561	18.5	105.58	25.3
Synedra	822	5.9	68.80	16.5
CHLOROPHYTA				
Chlorella	629	4.5	6.82	1.6
Chlorogonium	64	0.5	1.13	0.3
TOTALS	**13,843**	**100.0**	**416.89**	**100.0**
BACILLARIOPHYTA	13,150	95.0	408.93	98.1
CHLOROPHYTA	693	5.0	7.96	1.9

TABLE A-21

CONTROL SITE 2 (MATTAWOMAN CREEK TRANSECT W)
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cyclotella	264	6.7	4.73	4.2
Frustulia	132	3.3	5.44	4.8
Navicula	792	20.0	30.63	27.2
Stephanodiscus	132	3.3	41.53	36.9
Synedra	132	3.3	11.05	9.8
CHLOROPHYTA				
Chlamydomonas	132	3.3	0.52	0.5
Chlorella	1,057	26.7	11.47	10.2
Chlorogonium	132	3.3	2.32	2.1
Ulothrix	1,189	30.0	4.87	4.3
TOTALS	**3,962**	**100.0**	**112.56**	**100.0**
BACILLARIOPHYTA	1,452	36.6	93.38	83.0
CHLOROPHYTA	2,510	63.4	19.18	17.0

TABLE A-22

CONTROL SITE 2 (MATTAWOMAN CREEK TRANSECT C)
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cyclotella	185	14.3	3.31	9.1
Navicula	555	42.9	21.44	58.9
Surirella	185	14.3	7.62	20.9
CHLOROPHYTA				
Chlorella	370	28.6	4.02	11.0
TOTALS	**1,295**	**100.0**	**36.39**	**100.0**
BACILLARIOPHYTA	925	71.4	32.37	89.0
CHLOROPHYTA	370	28.6	4.02	11.0

TABLE A-23

CONTROL SITE 2 (MATTAWOMAN CREEK TRANSECT E)
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cocconeis	317	10.5	13.07	10.7
Cyclotella	158	5.3	2.84	2.3
Gomphonema	158	5.3	0.39	0.3
Navicula	792	26.3	30.63	25.0
Surirella	475	15.8	19.6	16.0
Synedra	634	21.1	53.06	43.3
CHLOROPHYTA				
Chlamydomonas	317	10.5	1.24	1.0
Chlorella	158	5.3	1.72	1.4
TOTALS	**3,009**	**100.0**	**122.55**	**100.0**
BACILLARIOPHYTA	2,534	84.2	119.59	97.6
CHLOROPHYTA	475	15.8	2.96	2.4

TABLE A-24

CONTROL SITE 2 (MATTAWOMAN CREEK TRANSECT) SUMMARY
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

February 1995

Taxon	Mean Density (cells/cm^2)	Relative Abundance (%)	Mean Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA				
Cocconeis	106	3.8	4.36	4.8
Cyclotella	202	7.3	3.63	4.0
Frustulia	44	1.6	1.81	2.0
Gomphonema	53	1.9	0.13	0.1
Navicula	713	25.9	27.57	30.5
Stephanodiscus	44	1.6	13.84	15.3
Surirella	220	8.0	9.07	10.0
Synedra	255	9.3	21.37	23.6
CHLOROPHYTA				
Chlamydomonas	150	5.4	0.59	0.6
Chlorella	528	19.2	5.74	6.3
Chlorogonium	44	1.6	0.77	0.9
Ulothrix	396	14.4	1.62	1.8
TOTALS	**2,755**	**100.0**	**90.50**	**100.00**
BACILLARIOPHYTA	1,637	59.4	81.78	90.4
CHLOROPHYTA	1,118	40.6	8.72	9.6