SECTION 316(a) DEMONSTRATION
(Type I)

SURRY POWER STATION - UNITS 1 and 2

Submitted to

Virginia State Water Control Board

by

Virginia Electric and Power Company

August 31, 1977

Docket # 50-280
Control # 7804180113
Date 8/10/78 of Document
REGULATORY DOCKET FILE

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I. INTRODUCTION

The Virginia Electric and Power Company (Vepco) announced plans in 1967 for the construction of a two unit nuclear powered electric generating station on Gravel Neck peninsula adjoining Hog Island in Surry County, Virginia (Fig. 1). Gravel Neck is located adjacent to the tidal oligohaline transition zone of the James River, a major tributary of Chesapeake Bay. This zone is centered around Hog Island and generally ranges from 46 to 63 km (25-34 nautical miles) upstream from the river mouth.

Unit 1 attained initial criticality on July 1, 1972, and Unit 2 attained initial criticality on March 7, 1973.

Vepco applied for a Section 316(a) demonstration on August 16, 1974, to be filed with the Virginia Water Control Board on September 1, 1977.

The following report constitutes a non-predictive demonstration (Type I, absence of prior appreciable harm), and is submitted in accordance with the provisions and regulations under Public Law 92-500 and Vepco's request of August 16, 1974. The data presented herein will demonstrate conclusively that the thermal effluent from Surry has not caused appreciable harm to the fish, shellfish, and wildlife in and on the waters of the James River. Such proof will constitute a successful Type I demonstration and render the Surry Power Station thermal discharge eligible for alternate thermal effluent limitations as provided in existing laws and regulations.

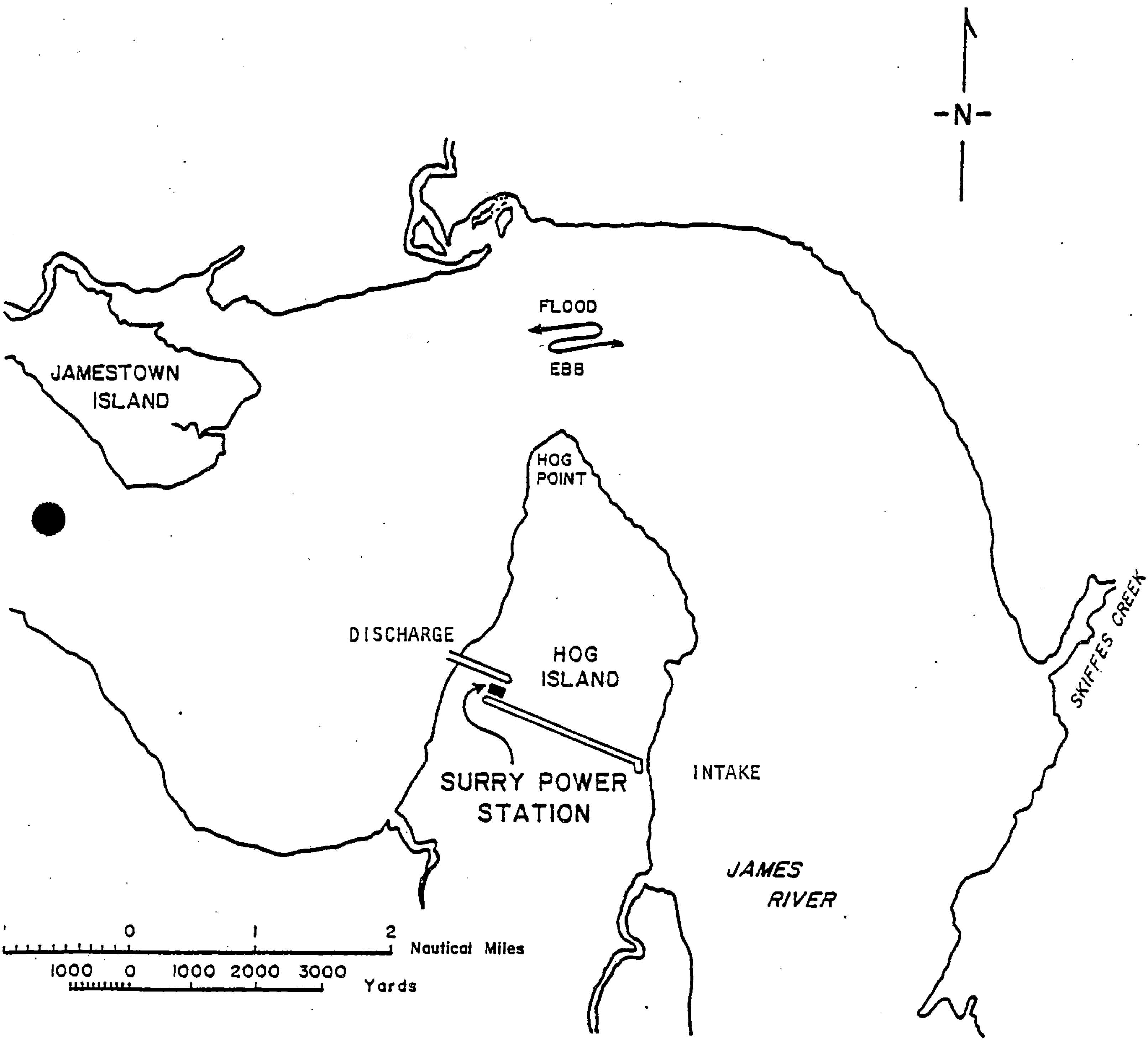


FIGURE 1: Location of Surry Power Station on the James River, Virginia.

II. MASTER RATIONALE FOR TYPE I DEMONSTRATION

Regulations of the Environmental Protection Agency (EPA) provide that a Type I demonstration (absence of prior appreciable harm) may permit the imposition of alternate effluent limitations where the applicant can demonstrate that "no appreciable harm has resulted from the thermal component of the discharge . . . to a balanced, indigenous community of shellfish, fish and wildlife in and on the body of water into which the discharge has been made . . ." 40 C.F.R. § 122.15(b)(1)(A) (1976). In order to conduct a Type I demonstration, Vepco has conducted and funded extensive physical and ecological studies in the vicinity of Surry Power Station. As discussed below and throughout this demonstration, data from these studies indicate that Vepco's Type I demonstration successfully meets the regulatory standard. The remainder of this master rationale discusses the requirements for conducting a Type I demonstration and the results of the physical and ecological studies.

The threshold question is whether an applicant may be permitted to conduct a Type I demonstration. Vepco submitted a Type I demonstration study plan to EPA with a copy to the State Water Control Board on October 14, 1974. This plan was approved on March 22, 1976. Also, Vepco satisfies the requirements for such a demonstration. According to EPA's regulations, a Type I demonstration may be conducted if it satisfies two requirements. First, an applicant must have been discharging heated effluent into a body of water for a sufficient period of time prior to its § 316(a) application to allow evaluation of the effects of the discharge. The preamble to EPA's regulations specifies that the minimum period between the commencement of thermal discharges and a § 316(a) demonstration should be one year. Vepco's Surry Power Station more than satisfies this requirement -- Unit 1 became critical on July 1, 1972 and Unit 2, on

March 7, 1973, and Vepco submitted its application on August 16, 1974. Moreover, Vepco has conducted or funded ongoing physical and ecological studies since the late 1960's including more than three years since its application for a § 316(a) demonstration. Thus, there is a substantial body of on-site thermal effects data with which to evaluate the influence, if any, of the discharge.

Second, the discharge must not have been into waters which are (or were) so despoiled as to preclude evaluation of the ecological effects of the thermal discharge. While the James River, at points upstream from Surry, might be considered despoiled, it is not despoiled in the vicinity of Surry because the station is located in the river's transition zone. As will be discussed later in this demonstration, this transition zone is one of relatively clean water since the pollution load in the river upstream is largely dissipated through natural processes before reaching Surry. Thus, the James River in the vicinity of Surry is not so despoiled as to preclude evaluation of the ecological effects of its thermal discharge.

Once it is established that a thermal effluent qualifies for a Type I demonstration, it is necessary to determine whether absence of prior appreciable harm can be demonstrated. To accomplish this entails comprehensive, long-term ecological studies in the area of concern; studies which involve communities from almost all trophic levels as well as selected species within communities. If the data from several years' duration indicate that the balanced, indigenous populations of fish, shellfish, and wildlife in and on the body of water under study are not being appreciably harmed by the thermal effluent, the demonstration should be found successful.

The circulating water system of Surry Power Station was designed to minimize the size of the thermal plume with the knowledge that such a design would minimize any possible impact on the aquatic ecosystem. During the design phase of Surry Power Station, Vepco contracted with Pritchard-Carpenter, Consultants, to utilize the hydraulic model of the James River estuary located at the U. S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi. The purpose of using the model was to develop an optimum discharge location, configuration, and exit velocity. The final design resulted in a relatively low delta-t effluent that mixes rapidly with ambient estuarine waters. This design minimizes any possible influence from the effluent on the environment by substantially reducing the area of excess temperature. Model tests also showed that by withdrawing water from the downstream side of Hog Point and discharging it into Cobham Bay upstream, any possible influence of the heated effluent on the downstream James River seed oyster beds would be eliminated.

The success of the design and the accuracy of the model have been verified by extensive field monitoring. The circulating cooling water system was designed, constructed, and operated according to hydraulic model parameters. Model verification field data were collected by VIMS from 1971 through 1975, and included several years of station operation. These field studies indicated that model projections were conservative in that areas of excess temperature were much smaller than predicted. Vepco concluded and the State Water Control Board has recently agreed that, under operating conditions, the thermal plume complies with Virginia water quality standards.

The most important component of this demonstration is Section X which describes the effects, if any, of Surry's thermal discharge upon various components of the aquatic ecosystem. In order to assess these thermal effects, Vepco has conducted and funded extensive studies on various trophic levels. Most of the proof of absence of prior appreciable harm is based upon these recent physical and ecological studies. In addition, the demonstration draws from studies of the James River ranging from water quality, to fishes, to power station effects which have been conducted by a myriad of sponsors for a multitude of reasons.

Field studies commenced in 1969, placing primary emphasis on fish populations and benthic communities. These studies also included fouling organisms, zooplankton and phytoplankton studies continued throughout several years of station operation. Depending on the trophic level under investigation, sample frequency ranged from daily to annually.

The sum total of these studies support two basic conclusions. First, the heated effluent from Surry Power Station has caused no appreciable harm to the aquatic ecosystem. Second, these studies confirm what is already well-known by estuarine ecologists. The oligohaline zone of an estuary is a highly variable, inhospitable environment characterized by its natural instability. Such instability dictates that only a few species from each trophic level are indigenous to this type zone. Other species that may be present in significant numbers, and there are many of these, are temporary inhabitants and are present when environmental conditions are suitable for their well being.

The highest trophic level, the finfish, have not been appreciably harmed by the thermal discharges from Surry Power Station. Communities have remained stable, within natural variability, as evidenced by diversity, evenness, and richness indices and confirmed by both parametric and non-parametric statistical tests. In addition, changes within dominant species, where changes were evident, were examined and determined to be the result of natural and man-made perturbations other than Surry. Also, the thermal plume from Surry was determined not to form a barrier to migratory fishes based on studies of various anadromous species such as blueback herring (Alosa aestivalis). During six years of study, fishes of the James River from egg stage through adult, were subjected to a wide variety of environmental insults. Hurricane Agnes flooded the lower estuary with freshwater runoff. Certain species were overfished. Mild as well as extremely cold winters were the rule rather than the exception. Chemicals such as chlorine from sewage treatment plants as well as Kepone resulted in unknown consequences.

As to ichthyoplankton, relatively few eggs and larvae were found because little spawning occurs in the vicinity of Surry. Centers of spawning abundance are known to be well upstream and downstream. VIMS determined that those eggs and larvae present in the area were not being entrained by the thermal plume.

Benthos (including shellfish) and fouling organisms have not been appreciably harmed by the thermal effluent. Rather, studies have served largely to confirm the well-known low diversity and high temporal variability in communities of an estuarine transition zone. Change has occurred, largely in community structure but has not been related to the thermal effluent. Change, however, appears related to natural events such as Hurricane Agnes, depressed salinity levels, elevated wintertime temperatures, and minimum wintertime temperatures. Natural, environmentally induced changes, have overshadowed any response of these communities that may have been due to the power station effluent.

Results of plankton studies by VIMS revealed no appreciable harm from the thermal plume to James River communities of phytoplankton and zooplankton (including egg and larval stages of benthic macroinvertebrates). Natural periodic seasonal shifts in species dominants related to normal reproductive cycles, not Surry produced temperature regimes, were found. A slight modification in community structure during the summer months was found within the discharge canal and in a small area immediately outside of the canal, but not in the balance of the river. It should be noted that, while this was the only seemingly negative effect found in any of the studies related to Surry operations, the effect was due to pumping operations across the peninsula, was not a thermal effect, and did not constitute an impact. In reality, plankton populations in the plume were sometimes diluted when the downstream water was poorer in plankton than the upstream receiving water, and were augmented when the downstream water was richer in plankton or when meroplankton were released into the cooling water canals by natural spawning activity. These were near-field, non-thermal effects that could not be detected in sampling at other stations in the river.

From these studies the following conclusions have been made:

1. These studies demonstrate that there has been, and is likely to be, no appreciable harm to the balanced, indigenous community of shellfish, fish, and wildlife in and on the James River resulting from the thermal discharge from Surry Power Station.

a. Finfish populations have shown natural variability within and between species, sample stations, months, seasons, and years. The increase or decline of any given species has not been the result of the thermal effluent from Surry. A zone of passage has not been impaired to the extent that fish and shellfish species are unable to pass upstream and downstream past the thermal discharge.

b. Benthic organisms, including shellfish, have not displayed a negative response to, or impact from, the Surry thermal effluent.

c. Fouling organisms exhibited seasonal variation patterns that changed from year-to-year in response to natural factors and indicated no appreciable harm from the Surry thermal effluent.

d. Zooplankton populations, while generally low in numbers, showed considerable variability in abundance within and between stations, months, and seasons, as well as depth, tide, and time of day. The zooplankton community in the transition zone was not appreciably affected by the thermal effluent.

e. Phytoplankton populations did not react to the thermal component of the Surry discharge. An infrequently observed pumping effect in the immediate discharge area consisted of augmentation (both species and individuals within species) or reduction depending on the comparative concentration of cells between the intake and discharge. Far-field populations showed no changes due to this non-thermal pumping effect.

f. There has been no harm to threatened or endangered species.

g. Vertebrates other than finfish have not been appreciably harmed by the Surry thermal effluent.

2. Receiving water temperatures, outside the State established mixing zone, comply with thermal water quality standards.

3. The receiving waters are not of such quality that in the presence or absence of the thermal discharge promote the growth of nuisance organisms.

III. DESCRIPTION OF SURRY POWER STATION

A. PHYSICAL LAYOUT

Units 1 and 2 were constructed on a peninsula of land known as Gravel Neck (Fig. 1). This peninsula, generally land of 20+ feet MSL, is adjacent to Hog Island Waterfowl Refuge on the north, and timber lands to the south. Prior to construction, the 840 acre site was used solely for timber operations.

The station, from intake point to discharge point, extends across the peninsula with the discharge situated upstream from the intake, about 6 miles away.

Cooling water is withdrawn from the James River through an eight-bay, reinforced-concrete intake structure (hereinafter called "low-level"). Housed within each of the intake bays is a 210,000 gpm circulating water pump which moves water through a 95-in. diameter line to an elevated intake canal. The canal, maintaining a minimum of 45,000,000 gallons of water, is concrete lined and about 1.7 miles in length.

Cooling water flows by gravity the entire length of the canal (hereinafter called "high-level") into two four-bay intake structures, each structure serving one 810 MWe nuclear unit. After passing through the condensers and station proper, the water from both units, warmed by about 15 F, flows into a common discharge canal, 20-65 feet wide and 2,900 feet long. The end of the canal at the point of exit to the James River is designed to maintain a 6 fps discharge velocity to aid in the rapid mixing of heated water with ambient river water.

B. PERTINENT ENVIRONMENTAL DESIGN CHARACTERISTICS

Certain features of environmental significance were incorporated into the design of the Surry Power Station. Because of the proximity of the station to historical Jamestown Island, the reactor containment foundations were constructed 50 feet below grade so as to lower the tops of the concrete domes and minimize their effect on the skyline as seen from across the river. A blue-green siding for the turbine building was chosen to help to blend the structure into the forest background. The discharge canal, lined with trees, was constructed with an offset angle to minimize the view of the station from the river.

No chlorine is used for condenser cleaning at Surry Power Station. Instead, an Amertap system was installed, utilizing abrasive sponge rubber balls.

A relatively low delta-t of 15 F was designed into the cooling system. This feature, coupled with the 6 fps jet discharge of heated water to the river, reduces the area of excess temperature in the James River proper.

Probably the feature of most significance to the aquatic environment of the James River was the design, construction, installation, and, above all, successful operation of a new concept in vertical travelling intake screens - the Ristroph travelling fish screen. These screens are discussed in detail in Appendix S; briefly, they permit 94% of all impinged fishes to return alive to the James River.

C. CIRCULATING WATER SYSTEM

Surry Power Station utilizes a once-through system to dissipate waste heat from the turbine condensers and plant service water system (Fig. 1). Water is withdrawn from the James River by eight 210,000 gpm pumps in an eight-bay shoreline structure. Ahead of each pump is a standard trash rack (4 inches on center, 1/2 inch thick, 3 1/2 inch clearance). Between each trash rack and pump is a Ristroph travelling fish screen which effectively removes fishes greater than 30 mm total length from the incoming water and safely transports about 94% of them back to the James River.

From the pumps, water travels upward through 95 inch diameter pipes to an elevated, 1.7 mile long canal, whereby it flows by gravity through a second intake structure. This high-level structure has a trash rack assembly similar to the one at the low-level structure, and conventional vertical travelling screens which operate on a pressure differential. Water passes through the 15 F condensers of each unit and into 12.5-ft. by 12.5-ft. rectangular tunnels and then into separate seal-pits in the discharge canal. The canal is 2900 feet in length; 1800 feet is concrete lined and extends from the unit discharges to the river shoreline, and 1100 feet extends out into the river in the form of a limestone rock enclosed groin (Fig. 1).

The velocity of the water flowing through the discharge canal is about 2 fps, however, the terminal discharge velocity is maintained at 6 fps by a control structure at the end of the canal. The time required for water to travel from the low-level shoreline intake structure to the discharge canal exit is about 61 minutes, of which the time of travel from the condenser inlet to the discharge canal exit is about 28 minutes.

In full-power operation, the Surry Power Station discharges 11.9 x 10^9 Btu/hr into the James River. Dissipation of the thermal plume is dependent on prevailing estuarine and meteorological conditions including, but not limited to: the flow regimes of the estuary, their associated densities and temperatures, wind velocities and direction, ambient air temperatures, and relative humidities.

River topography is also important in determining the manner of heat dissipation. The river in the vicinity is generally shallow with a maintained shipping channel. Directly across from the discharge toward Jamestown Island the river is about 2.6 miles wide. At its narrowest, opposite Hog Point, the river is 1.5 miles wide, and becomes about 3.75 miles wide opposite the low-level intakes.

IV. SURRY POWER STATION OPERATING HISTORY

Surry Unit 1 attained initial criticality July 1, 1972, and was declared commercial December 22, 1972. Unit 2 became critical March 7, 1973, and was declared commercial May 1, 1973. The following Tables (1-4) list net electrical output (MW-hrs) and plant capacities (%) from the time each unit became critical through June 1977.

Surry Power Station utilizes eight (8) circulating water pumps to supply cooling and service water from the James River for the condensers. When all eight (8) circulating water pumps are in operation, the combined flow is 1,680,000 gpm or 210,000 gpm per pump.

Figure 2 indicates current velocities at the low-level intakes. These data were determined utilizing a Bendix Savonius Rotor Current Speed Sensor Model B-1. Replicates were taken surface to bottom at one foot intervals outboard of three (3) intake bays.

The change in temperature (delta-t) of the cooling water when both units are operating at 100% capacity and all systems are functioning, varies between 14.0 and 14.8 F. If both units are operating and a malfunction in the system occurs, eg., loss of a circulating water pump, there may be a subsequent slight increase in the delta-t.

The groin discharge structure was designed to maintain an exit current velocity of approximately 6 fps. This design was established from model studies so that the velocity of the discharge water would permit maximum heat transfer efficiency with ambient river water.

TABLE 1: SURRY POWER STATION - UNIT ONE -
NET ELECTRICAL OUTPUT IN MEGAWATT-HOURS

	1972	1973	1974	1975	1976	1977
January		76,582	-0-	-0-	561,212	139,519
February		351,949	-0-	412,497	517,366	456,863
March		345,220	251,119	431,941	376,648	568,732
April		313,633	503,663	462,515	426,326	195,185
May		337,327	478,272	530,894	465,205	308,286
June		266,603	498,838	477,277	527,763	551,480
July	30,252	445,294	326,556	407,891	395,817	
August	-0-	409,375	548,037	487,651	416,802	
September	78,764	284,190	468,107	429,467	422,821	
October	31	159,011	243,481	-0-	286,925	
November	-0-	490,569	-0-	-0-	-0-	
December	206,937	-0-	-0-	276,394	-0-	

TABLE 2: SURRY POWER STATION - UNIT TWO -
NET ELECTRICAL OUTPUT IN MEGAWATT-HOURS

	1972	1973	1974	1975	1976	1977
January			493,276	424,102	387,305	547,338
February			427,329	480,554	371,511	174,425
March		57,436	526,222	514,153	449,305	-0-
April		255,450	229,597	427,911	358,361	349,246
May		147,294	-0-	-0-	-0-	564,584
June		466,755	51,204	216,234	355,272	543,470
July		410,548	401,279	458,372	527,570	
August		450,028	400,622	513,134	505,862	
September		481,628	104,944	497,651	258,516	
October		409,633	-0-	424,714	-0-	
November		223,365	-0-	542,529	-0-	
December		475,475	-0-	553,728	129,619	

TABLE 3: SURRY POWER STATION - UNIT ONE - PLANT CAPACITY %

	1972	1973	1974	1975	1976	1977
January		13.1	-0-	-0-	95.7	23.8
February		66.6	-0-	78.0	94.3	87.7
March		58.9	42.1	73.7	64.2	98.6
April		55.4	88.8	81.5	75.1	35.0
May		57.5	78.2	90.6	79.3	53.5
June		47.0	84.3	84.1	93.0	98.8
July	5.1	76.0	53.4	69.5	67.5	
August	-0-	69.8	93.4	83.2	71.1	
September	13.9	50.1	82.5	75.7	74.5	
October	0.005	27.1	41.5	63.3	48.9	
November	-0-	86.5	52.5	57.6	-0-	
December	44.5	-0-	32.7	47.1	-0-	

$$\text{Plant Capacity} = \frac{\text{Net Elec. Power Generated}}{\text{Cur. Lic. Power Level (788)xGross Hours in Reporting Period}} \times 100$$

TABLE 4: SURRY POWER STATION - UNIT TWO - PLANT CAPACITY %

	1972	1973	1974	1975	1976	1977
January			87.7	72.3	66.0	93.4
February			78.9	90.7	67.7	33.5
March		9.8	87.8	87.7	76.6	0
April		45.1	38.8	75.4	63.2	62.7
May		25.1	56.2	64.7	0	97.9
June		82.2	8.6	38.1	62.6	97.4
July		70.0	65.6	78.2	90.0	
August		76.8	68.3	87.5	86.3	
September		84.9	18.5	87.7	45.6	
October		69.8	45.8	72.4	0	
November		39.3	41.7	95.6	0	
December		81.1	38.2	94.4	22.1	

$$\text{Plant Capacity} = \frac{\text{Net Electric Power Generated}}{\text{Cur. Lic. Power Level (788)} \times \text{Gross Hours in Reporting Period}} \times 100$$

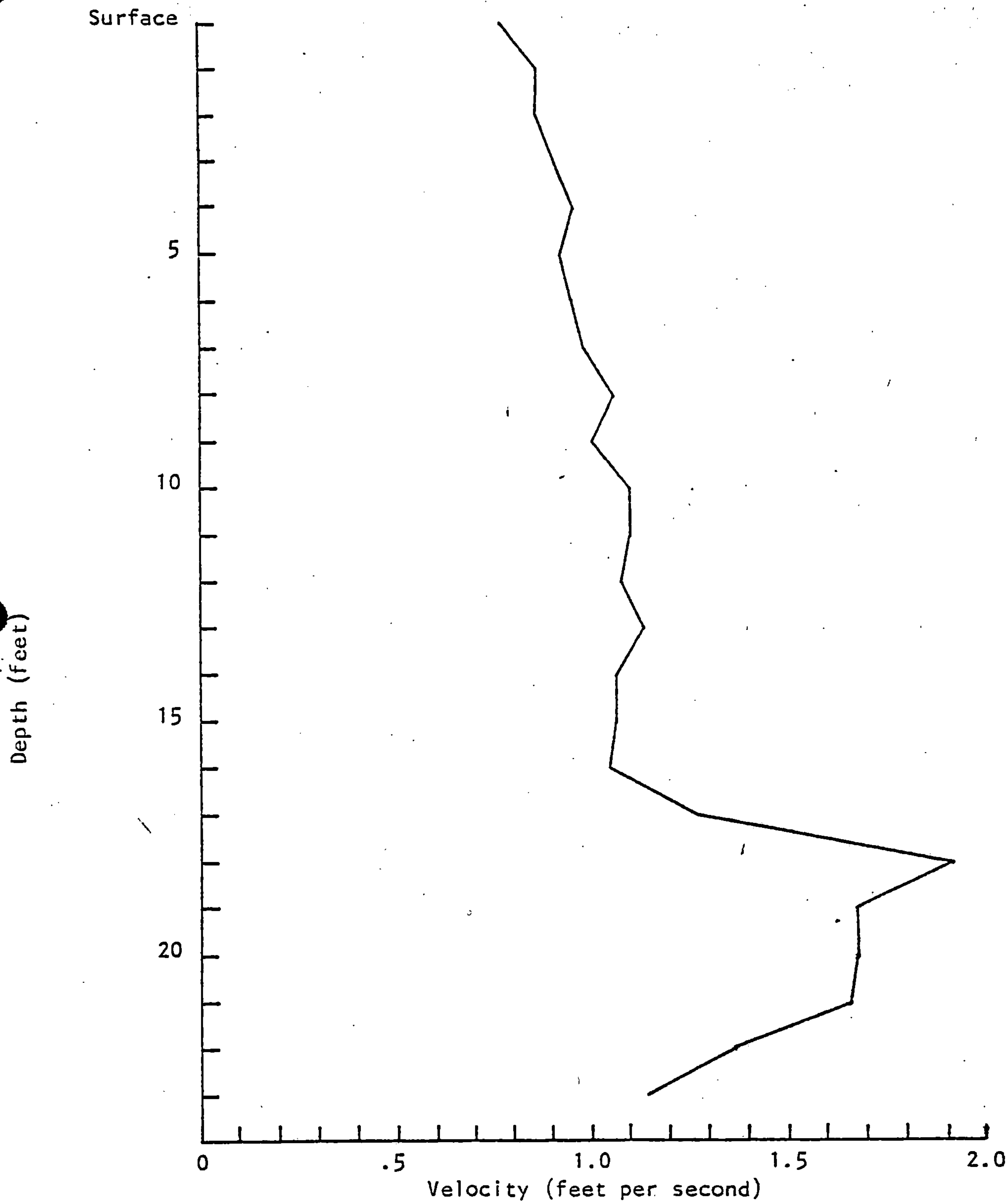


FIGURE 2: Typical Intake Current Velocity

V. DESCRIPTION OF THE TIDAL JAMES RIVER AND TRANSITION ZONE

A. HYDROLOGY

The James River is tidal from its mouth at Fort Wool to its fall line at Richmond. Upstream from the site at Surry, the James is fed by a drainage area of 9517 square miles. Freshwater inflow from this watershed is highly variable, ranging from a mean monthly average low of 350 cfs in October, 1930, to a mean monthly average high of 36,185 cfs in January, 1937. Hurricane Agnes in June, 1972 caused the flood of record in the James River with a flow of 313,000 cfs.

The tidal James River is classified as a partially mixed estuary where salinity decreases in a more or less regular manner from the mouth toward the transition zone, and also increases with depth at any location.

The less saline upper part of the water column has a net non-tidal motion directed toward the mouth of the James, while the more saline deeper part has a net non-tidal motion directed upstream. The boundary between the layers is generally sloped across the estuary so that the downstream moving surface layer extends to greater depths on the right side (looking downstream) than on the left. Conditions can exist whereby a net downstream flow on the right side of the estuary coexists with a net upstream flow on the left side.

Basically this means that the net non-tidal flow involves volumes of water that are large when compared to river flow, but small compared to oscillatory tidal flow. For example, in July, 1950, the fresh water discharge at Hog Point was about 6,000 cfs, the downstream directed flow in the surface layers was 18,000 cfs, and a counter-flow upstream in the deeper layers was about 12,000 cfs. By comparison, the average volume rate of flow (upriver during flood tide, downriver during ebb tide) was about 130,000 cfs during this time.

Flow records for the James River have been maintained for many years at the farthest downstream gaging station on the main stem at Richmond (Fig. 3). Using these records and records from major tributary streams downstream from Richmond, fresh water inflows at Hog Point have been calculated. It should be noted that the mean travel time for a flow of 14,000 cfs from Richmond to Hog Point is in excess of 20 days. This results in a relatively slow reaction time of the estuary at Hog Point to rapid fluctuations in flow at Richmond. The effects of rapid changes at Richmond are dampened considerably by the time the water reaches Hog Point.

The astronomical tide in the James River estuary, as along the Atlantic coastline of the United States, is primarily semi-diurnal with two high and two low waters each lunar day of 24.84 hours. Mean tide level at Hog Point (based on a datum plane of mean low water) is +1.0 foot. Mean tidal range is 2.1 feet and the mean spring tidal range is 2.5 feet.

At Hog Point the ebb current is longer and stronger than the flood current. The average maximum ebb current is 2.2 ft. sec^{-1} (1.3 knots) while the average maximum flood current is 1.9 ft. sec^{-1} (1.1 knots). Spring tides have maximum ebb currents of 3.2 ft. sec^{-1} (1.9 knots) and maximum flood currents of 2.8 ft. sec^{-1} (1.6 knots). Current ebbs for 7 hours 5 minutes and floods for 5 hours 20 minutes during a typical tidal period of 12 hours 25 minutes. Since these figures are based on near surface observations, it should be noted that the predominance of ebb over flood decreases with decreasing river discharge and often depth.

The salinity structure in the James River has been studied almost every year since 1942. Hog Point has been established to be in the transition region between the tidal river and the estuary proper. Areas upstream and

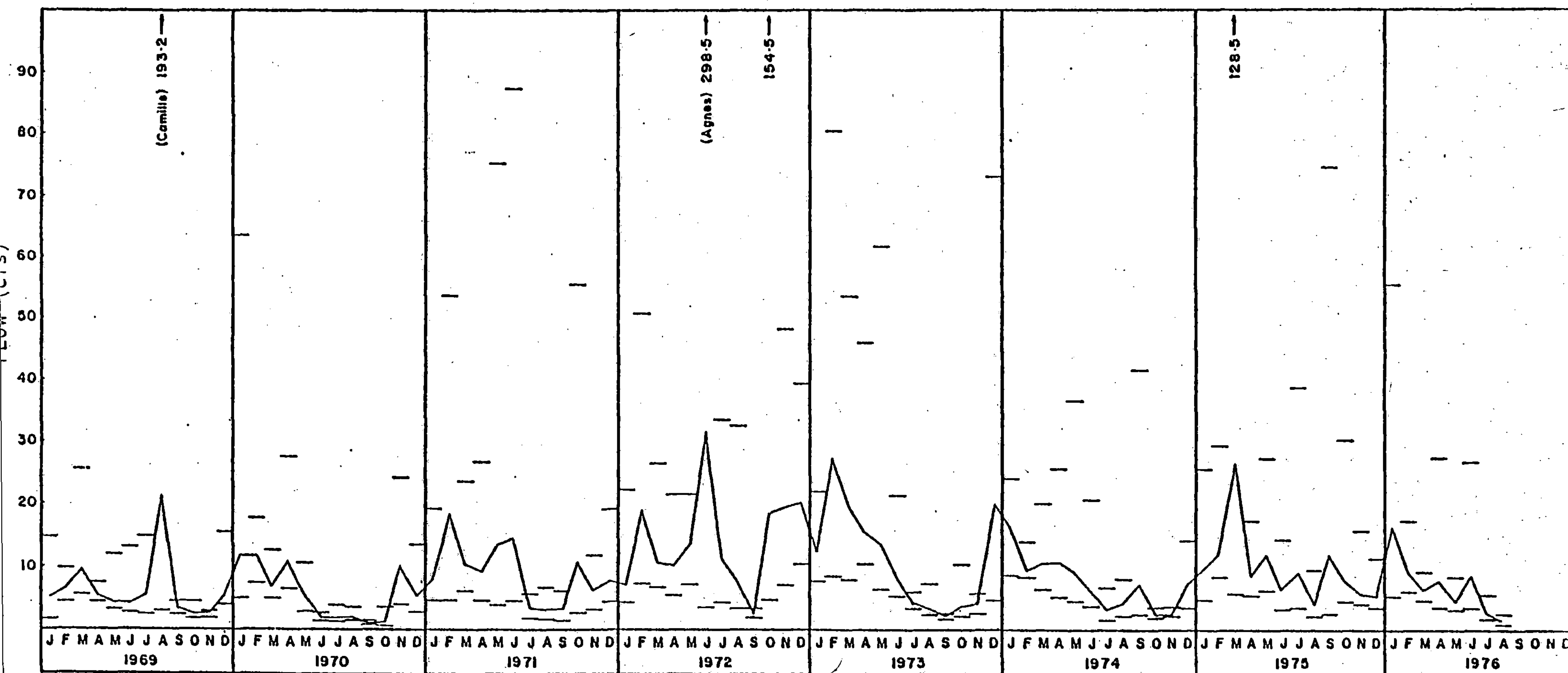


FIGURE 3: Flow records of the James River at Richmond (1970-1976) showing monthly maxima, minima, and averages.

downstream from Hog Point are subject to a wide range of salt concentrations, primarily depending on freshwater river flow. Above 10,000 cfs, the freshwater/saltwater interface moves downstream of Hog Point. At median river flows of about 7,500 to 8,000 cfs, salinity readings off Hog Point are about 2 ppt.

High discharge rates in the James River occur generally in the colder months with low flows occurring generally in late summer and early fall.

For a more detailed description of the hydrology of the James River estuary see Appendix C from which much of the foregoing summary has been drawn.

B. METEOROLOGY

The Surry Power Station is located in a humid subtropical climate which has warm humid summers and mild winters. Tropical maritime air dominates the area during the summer months while the winter season is dominated by a transition zone separating polar continental and tropical maritime air masses. The site's close proximity to the Atlantic Ocean, Chesapeake Bay, and the Appalachian Mountains results in these geographic features influencing the local climate in the Surry area. The Atlantic Ocean and the Chesapeake Bay have a moderating effect on the ambient temperature at Surry. The Appalachian Mountains either deflect or modify winter storms approaching from the West and Northwest and, thereby, decrease the storms' severity for the Piedmont and Tidewater areas of Virginia.

The onsite meteorology has been monitored since March, 1974 by a mini-computer based system which satisfies the requirements of Regulatory Guide 1.23. The meteorological monitoring site is located 1494 meters to the southeast of Unit 1. The system includes a 45.7 meter tower. Dry bulb temperature, dew point temperature, wind speed, and wind direction are measured at the 10 meter level. Wind speed and wind direction are measured at the 45.7 meter level. Differential dry bulb temperature is measured between the 10 meter level and the 45.7 meter level. Precipitation is measured at the surface. The data are processed into one hour averages for historical storage.

Joint frequency distributions of wind speed and wind direction for the wind sensors at the 10 m and the 45.7 m levels for the period March, 1974 through February, 1977 are presented in Appendix B. A summary of the maximum one hour averaged wind speeds and their associated wind directions for the 10 m and the 45.7 m wind sensors for the period March, 1974 through February, 1977 is also presented in Appendix B. The data show that the prevailing wind direction is from the S through SW with a secondary maximum from the NW through N. This is in good agreement with climatological wind direction data for eastern Virginia.

Dry bulb temperature, dew point temperature, and differential dry bulb temperature data are presented in Appendix B for the period March, 1974 through February, 1977. The average daily value, maximum one hour value, and minimum one hour value are given for each parameter. Additionally, an hourly profile of the average parameter day for each summary period is presented. The Surry dry bulb temperature data indicate an annual average of 59.9 F and 57.8 F for 1975 and 1976 which agrees very well with the average annual temperatures for Richmond (58.5 F and 57.7 F) and Norfolk (60.8 F and 59.7 F) for the same periods.

The Surry average annual dew point temperatures of 50.6 F and 45.1 F for 1975 and 1976 compare favorably with estimated average annual dew point temperatures for Richmond (50 F and 47 F) and Norfolk (52 F and 48 F). The one hour averaged dew point temperature extremes are 78.9 F (August, 1975) and -4.5 F (January, 1977).

The onsite precipitation data are also given in Appendix B. The maximum 1, 6, 12, 18, and 24 hour precipitation amounts and the total precipitation are given for each month during the period March, 1974 through February, 1977. The monthly total precipitation data for Surry are also given. The Surry annual precipitation amounts for 1975 and 1976 are 59.07 in. and 32.66 in. These amounts compare very well with the precipitation totals for Richmond (61.31 in. and 34.76 in.) and Norfolk (50.53 in. and 32.36 in.) for the same periods.

Based upon the onsite wind speed, wind direction, dry bulb temperature, and dew point temperature data observed at Surry for the period March, 1974 through February, 1977, there are no significant deviations in the onsite meteorology from the general meteorological conditions experienced by eastern Virginia for the same period.

C. WATER QUALITY

1. Chemistry

The James River is the most heavily industrialized and urbanized of Virginia's major tributaries to Chesapeake Bay. In addition to receiving substantial artificial enrichment from forest and agricultural sources, the tidal river receives heavy organic and inorganic loadings from both the metropolitan Richmond and the industrialized Hopewell areas.

Levels of dissolved oxygen in the James River estuary, as in other estuarine systems, are determined largely by temperature and salinity influenced solubility coefficients. In addition, man-made or natural organic loadings which create an oxygen demand exceeding reaeration rates also influence this coefficient. Lower portions of estuaries generally range between 90 and 100 percent saturation, while upper reaches frequently fall below 90 percent due to marsh drainage and industrial wastes. In the James River, reaeration generally occurs between the transition zone and the 5 ppt isohaline and "critical" levels have not been measured around Hog Point.

Values for pH levels show that the James River estuarine and tidal fresh water is slightly alkaline with mean values of 7.4-8.0 (Appendix D). An occasional value as low as 6.8 has been recorded in the freshwater reach which has been attributed to marsh drainage water. Biological activity or minor influences by man seldom cause significant changes in pH levels. In general, mean pH values tend to decrease from the mouth upstream to the fall line although the range of values becomes wider upstream with decreasing salinity.

Alkalinity values tend to show differences with decreasing salinity in the James River because the freshwater discharge in this system is poorly buffered. Mean values range from 1.50 $meq \cdot l^{-1}$ (1.26-1.71) at the 20 ppt isohaline to 0.69 $meq \cdot l^{-1}$ (0.41-1.18) at the 0 ppt isohaline.

Phytoplankton productivity in natural waters depends largely on the primary nutrients nitrogen and phosphorus. Added to trace substances these elements are discharged in large amounts into estuarine waters through runoff from farmland, sewage treatment facilities, detergents, and certain industrial activities.

Total nitrogen levels in the tidal James River are generally indicative of upstream loadings. While nitrate plus nitrite values tend to remain constant within the system at any given time, soluble organic nitrogen and particulate organic nitrogen levels varied with freshwater discharge.

Phosphorus levels are generally related to loadings from artificial sources, especially sources in Richmond and Hopewell. During the summer and fall months, the highest soluble phosphorus levels tend to be found near the mouth of the James River indicating that this form is coming from lower Chesapeake Bay or the Atlantic Ocean. Wintertime and springtime values show that total particulate phosphorus was the dominant form and these levels were generally related to high freshwater discharges during these seasons.

2. Salinity

The James River is tidally influenced from its mouth at Ft. Wool in Hampton Roads upstream to the fall line at Richmond, about 90 nautical miles. In times of low freshwater inflow, measurable ocean-derived salt water can be found as far upstream as Hopewell, although the upstream limit at median river flows is generally between Jamestown Island and the Chickahominy River. When river discharges are greater than 14,000 cfs, the boundary between the fresh water tidal river and the estuary proper is downstream from Deep Water Shoals. Thus, salinities exceeding 0.5 ppt occur off the downstream intakes about 75% of the time while the upriver limit of salt intrusion extends above the upstream discharge point more than 50% of the time.

According to data appearing in Appendix C , the following salinity ranges have been observed in the vicinity of Surry Power Station:

Off intakes: Surface - 0.0 to 16.95 ppt.
at 25 ft. - 0.0 to 21.13 ppt.

Off Hog Point: Surface - 0.0 to 12.20 ppt.
at 20 ft. - 0.0 to 14.20 ppt.

Off discharge: Surface - 0.0 to 9.19 ppt.
at 20 ft. - 0.0 to 11.16 ppt.

While these ranges were observed from 1942 through 1965, the upper limits recorded have not been measured from 1969 through 1976, the time period for Surry preoperational and operational studies (Fig. 4).

For a more detailed description of the salinity structure of the James River estuary, see Appendices C and D.

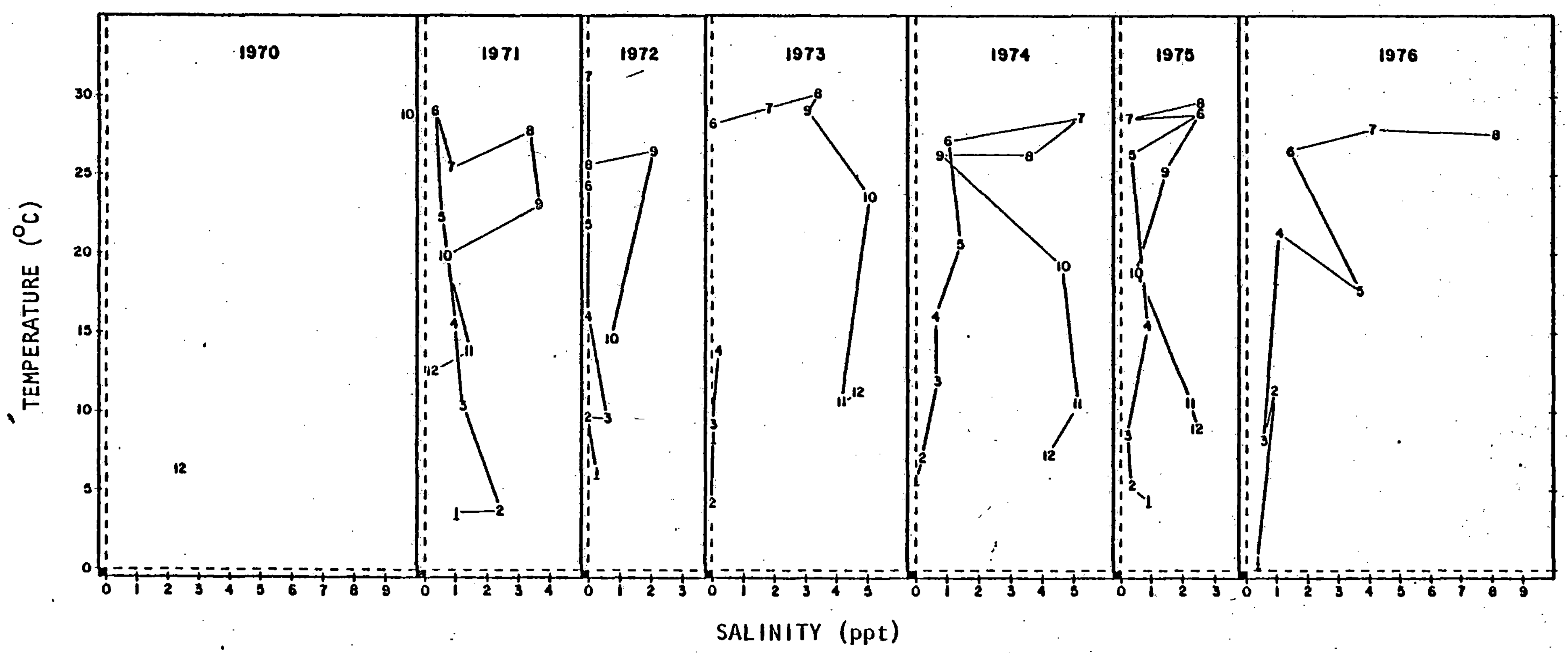


FIGURE 4: Temperature-salinity hydroclimographs showing average conditions for seven seine stations around Hog Point, James River, Virginia by month by year, 1970-1976.

3. Temperature

As with salinity, the temperature structure of the James River has been studied in detail since 1942. Surface water temperatures historically have closely followed the mean daily air temperature, except for a slight lag in the spring when air temperatures rise rapidly, and in the fall when they cool rapidly. Temperature-salinity hydroclimographs are presented in Figure 4.

Prior to station operation, the maximum surface water temperature measured in the area was 33.8C (92.8F) while the minimum was 0.0C (32F) when this stretch of the river iced over in 1969. While the majority of summer surface water temperatures fall in the range of 26-28C (78.8-82.4F), temperatures exceeding 30C (86F) are commonly found.

During the spring and summer water temperatures generally decrease with depth. A vertical gradient of about 4C is present over 20 feet of depth in the spring while the gradient is about 1-2C in the summer. In the fall, the temperature is approximately isothermal with wintertime temperatures increasing slightly with depth.

It should be noted that because surface water temperatures closely track air temperatures, differences in surface water temperature patterns between years and between months of successive years can be considerable. A prolonged season such as winter can result in an "out-of-phase" spring or even an abbreviated spring if summer air temperatures occur on schedule. A prolonged winter can, for example, result in an increasing day-length occurring with cool water whereby water temperatures would "normally" be increasing along with day-length. These situations can adversely influence the normal biological processes of many species.

Minimum water temperatures can occur in December, January, February, or March while maxima can occur in July, August, or September.

More detail on the temperature structure of the James River before Surry Power Station operation can be found in Appendices C and D.

VI. HISTORICAL ECOLOGY OF THE TIDAL JAMES RIVER AND TRANSITION ZONE

Aquatic populations of the James River have been studied for many years and a bibliography of these studies has been compiled by Virginia Institute of Marine Science (Appendix A). Generally, many of the investigations have examined the tidal James from its mouth at Fort Wool to the fall line at Richmond. Reference to the oligohaline or transition zone, where Surry Power Station is situated, is contained in these publications.

The following brief synopsis is a general characterization of the tidal James River taken from these many publications, with emphasis on the transition zone at Surry.

A. FINFISH

The tidal James River supports a wide diversity of finfish species ranging from exclusively marine forms near the mouth to exclusively freshwater riverine forms at the fall line in Richmond. Also present at various life stages, depending on the season, are both anadromous and catadromous species. Extensive commercial and sport fisheries exist within the tidal James although the activities of both have been severely curtailed in recent years due to chemical contamination of the basin waters.

Limited localized surveys of the James River fish fauna have been conducted for many years. However, no systematic survey of the entire basin has ever been attempted. The Virginia Institute of Marine Science (VIMS), through its anadromous fish program and winter trawl survey, has probably been the most instrumental in characterizing the fishes of the tidal James River. Vepco has characterized the faunas of the upper tidal James and the transition zone. About 80 species have been taken in the transition zone and 40 in the upper tidal river.

Population densities for any given species will vary by several orders of magnitude depending on the season of the year and the location within the basin where such a determination was made. Variation of a similar magnitude also occurs between years. Long-term studies have shown that probably the most numerous estuarine species on an annual basis tend to be the indigenous forage forms such as the bay anchovy, *Anchoa mitchilli*, and silverside, *Menidia* spp., as well as nondescript forms such as the hogchoker, *Trinectes maculatus*.

The tidal James River contains meroplanktonic forms from marine, estuarine, freshwater, anadromous, and catadromous fish species that spend all or part of their life cycles in these waters. Few fish eggs, however, are found in the vicinity of Surry Power Station because the true estuarine species generally spawn at salinities higher than 5 ppt, while the freshwater and anadromous forms spawn upriver from the 0.5 ppt isohaline. Salinities in the vicinity of Surry are usually between these values but can vary between 0 ppt and about 15 ppt.

Larval stages of several species, transported largely by tidal action, are found in the transition zone. Some species, especially marine and estuarine, use this zone as a nursery. Among the more notable are postlarvae of the Atlantic croaker, Micropogon undulatus and the Atlantic menhaden, Brevoortia tyrannus.

The tidal James River has been the site of several large fish kills over the last several decades. Despite these kills, the resiliency of the system has been shown as affected populations have tended to recover, some more quickly than others. Fish diversity in the tidal basin has remained relatively stable.

More detailed analyses of historical fish populations in the tidal James River appear in Appendices A and E.

B. BENTHOS

Bottom dwelling species are found in the James River estuary from the mouth to the fall line. Variation is considerable, changes occurring not only with longitudinal distance upstream (Fig. 5), but with sediment type and depth within an area as well.

Shellfish, from the transition zone downstream form the bulk of the benthic biomass encountered in the James River estuary. The brackish water clam, *Rangia cuneata*, dominates from fresh water to about 5 ppt salinity. The American oyster, *Crassostrea virginica*, occurs from about 5 ppt to about 20 ppt, while the hard clam, *Mercenaria mercenaria*, occurs extensively in higher saline parts of the lower estuary. In relatively recent times the Asiatic clam, *Corbicula* sp., has been found in the freshwater James in ever increasing numbers. The blue crab, *Callinectes sapidus*, occurs sporadically in the transition zone, with population concentrations downstream in more saline waters. Commercial quantities of penaeid shrimp are not present within Chesapeake Bay.

The diversity of benthic taxa is minimal in the transition zone, increasing maximally toward seawater and moderately upriver to freshwater. This distribution is not the result of a single environmental variable such as the oft-studied parameter salinity, but results from a combination of physical, chemical, and biological gradients which influence the genotypic physiological behavior and tolerance of all species from all sources. These variables collectively may limit the distribution of a species to a much greater extent than could be determined through laboratory experimentation on single factors. The ionic composition of the water *per se*, however, probably exerts the greatest influence on the distribution of benthic organisms.

More specific details on estuarine benthos in general and James River benthos in particular may be found in Appendices F and G.

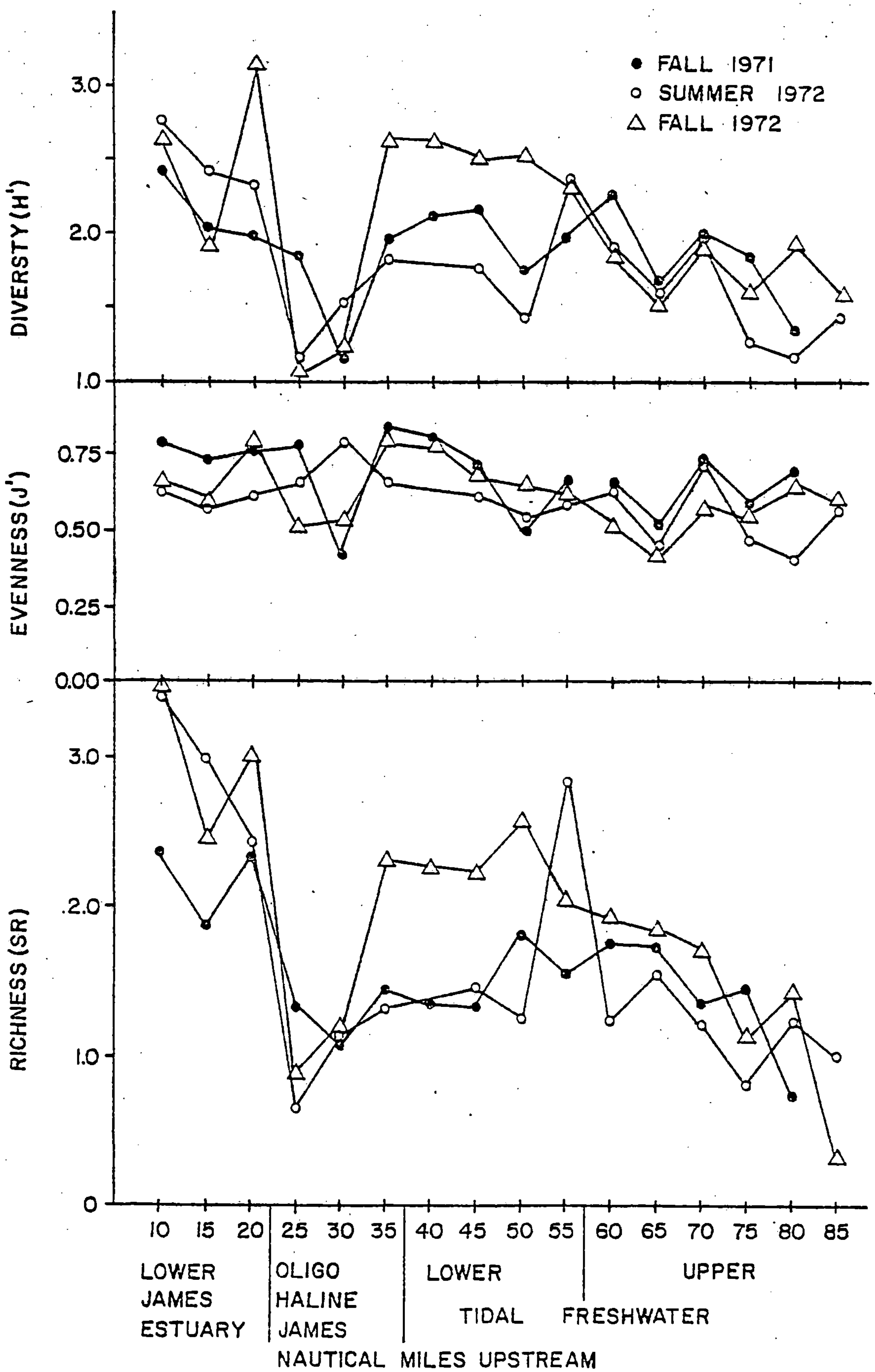


FIGURE 5: Mean benthic community structure measurements by transect. (from Appendix G)

C. FOULING ORGANISMS

One component of the infauna of benthic organisms that is usually highly visible but often little studied are the fouling organisms. These organisms in estuaries are commonly composed of barnacles (Balanus spp.), hydroids, tube-secreting worms, and sea squirts.

Diversity in the transition zone is generally low due to the salinity gradient experienced over time while numbers within a given species may be relatively high (Appendices G and H).

D. ZOOPLANKTON

Historically, zooplankton abundance and composition in the James River has been closely related to phytoplankton abundance and turbidity levels. The fresh water component of the James River estuary supports relatively large populations of cyclopoid and calanoid copepods, however, the heavy organic load results in cladocerans being a common part of the zooplankton community. The estuarine component is volumetrically abundant but relatively limited as to the number of species. Reasons for this phenomena include a salinity gradient compartmentilization of species.

Whether the salinity is reduced going upstream or the salinity manifests itself going downstream from fresh water, there is an area where the most tolerant species of both environments coexist, the transition zone. At Surry, seasonal pulses are evident in both forms dependent, in part, on the salinity regime present at the time, as well as the prevailing temperature and turbidity levels. In addition to salinity zonation, temperature zonation is also known to occur.

Meroplankton includes those forms having a temporary planktonic stage (eggs, larvae, etc.) in their life cycle. Included are temporary planktonic stages of true benthic organisms and other invertebrates such as the blue crab, *Callinectes sapidus*, as well as fish eggs and larvae discussed previously.

Few egg stages are found in the vicinity of Surry Power Station. Such a phenomenon occurs because the true estuarine forms generally spawn at salinities higher than 5 ppt, while the freshwater and anadromous forms spawn upriver from the 0.5 ppt isohaline. Freshwater inflow and tidal action, however, result in limited numbers of both forms present in the transition zone.

Larval stages of several species, transported by tidal action, are found in the transition zone. Other species, such as the indigenous brackish water clam, Rangia cuneata, spawn in the transition zone with egg and larval stages tending to cluster within the zone of salinity tolerance.

The zooplankton fauna in the transition zone is usually dominated by copepod nauplii with occasional pulses of other forms. More detailed species information may be found in Appendices A and I.

E. PHYTOPLANKTON

The James River estuary, while probably the most highly enriched of Virginia's estuaries, is also one of the most turbid. High turbidity levels tend to reduce light penetration and hence phytoplankton populations; a condition usually found in the James.

The James contains both downriver saline and upriver freshwater species of phytoplankton with the transition zone around Hog Point having a mixture of the two. Standing crop, as determined by chlorophyll "a" determinations, will vary significantly at any given point in the estuary both within and between seasons, within and between years, and within and between stations. In the oligohaline zone it is not uncommon to find the fauna dominated by one or two species particularly well suited to existing environmental conditions.

The study area of the James is usually dominated by diatoms and cryptophytes with representatives from both freshwater and estuarine environments present. Primary productivity values, whether by $mgC/hr/m^3$ or by $\mu g^{-1} l^{-1}$, are extremely low in this zone.

Species lists appear in Appendices A and I. Individual species will be discussed in more detail in Section X-E of this demonstration.

F. THREATENED AND ENDANGERED SPECIES

The following species are listed as endangered (E) or threatened (T) by the U. S. Fish and Wildlife Service* as possibly occurring on or near the Surry Nuclear Power Station site.

<u>Fish</u>		
<u>Acipenser brevirostrum</u>	shortnose sturgeon	(E)
<u>Birds</u>		
<u>Haliaectus l. leucocephalus</u>	southern bald eagle	(E)
<u>Falco peregrinus anatum</u>	American peregrine falcon	(E)
<u>Falco peregrinus tundris</u>	Arctic peregrine falcon	(E)
<u>Pelecanus occidentalis</u>	brown pelican	(E)
<u>Dondrocopus borealis</u>	red-cockaded woodpecker	(E)
<u>Dendroica kirtlandi</u>	Kirtlands warbler	(E)

Only the southern bald eagle and American peregrine falcon are likely to have resident individuals during any given season of the year. All others would probably occur, if at all, only as migrants through the area.

* Federal Register, Wednesday, October 27, 1976, Vol. 41, No. 208, pp. 47181-47197.

G. VERTEBRATES OTHER THAN FINFISH

The only category of vertebrates coming under the jurisdiction of this classification that would be reasonably close to the thermal discharge at Surry would be waterfowl. Eastern Virginia lies within a major duck and goose migration route. Consequently, directly to the north of Surry Power Station, on Hog Island, the Commonwealth of Virginia owns and operates a waterfowl refuge that is annually visited by thousands of ducks and Canada geese. The refuge consists of many freshwater ponds as well as fields that are planted each year with waterfowl food.

VII. HISTORY OF THERMAL AND ECOLOGICAL STUDIES AROUND SURRY POWER STATION

Historically, the James River and its ecology have been under investigation for many years and a list of these studies has been compiled in an inclusive bibliography by VIMS (Appendix A). Although the majority of these studies were conducted under Federal, State or University sponsorship, private industry such as Vepco has also contributed extensively to knowledge concerning the James River (Appendices J and K).

Studies conducted and/or funded by Vepco with the Virginia Institute of Marine Science (VIMS) were initiated in 1969. These studies, designed to assess ecological consequences of operation of a nuclear generating facility on the oligohaline zone of the James River, include the following trophic levels or areas of interest: finfish, benthos, primary productivity, zooplankton, phytoplankton, and fouling plate communities. In addition, extensive model and field studies on thermal plume configuration have been conducted.

Studies related to an assessment of the aquatic ecosystem as influenced by the thermal plume were divided into three categories -- thermal plume model studies, field studies and laboratory investigations.

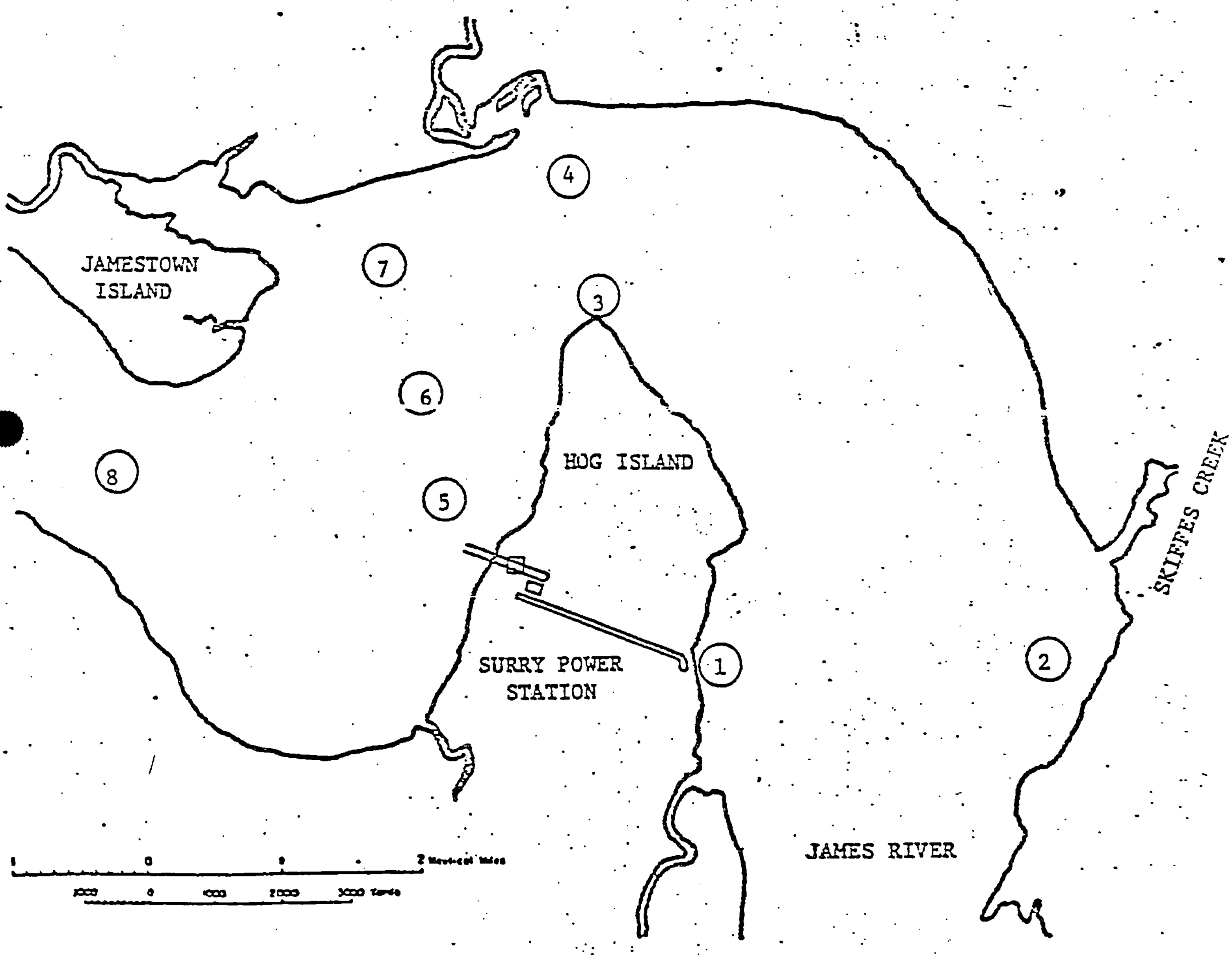
A. THERMAL MODEL STUDIES AND FIELD VERIFICATION

During the design phase of Surry Power Station, Vepco and its consultant (Pritchard-Carpenter, Consultants) employed the hydraulic model of the James River estuary at the U. S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi, to determine the best design features and location of the circulating water system (Appendix L). The results were incorporated into the design of the station and later checked by field studies when the station became operational.

A thermal monitoring system was designed and employed by VIMS and Vepco in order to better determine the region of the James River estuary which would be affected by the discharge of the Surry Power Station as well as to better determine the temperature distribution within that area. Three different measurement systems were utilized: (1) multi-sensor system located on a small boat serving as a mobile measurement platform, (2) multi-sensor system located on towers in the James River which served as fixed instrument platforms (Fig. 6), and (3) infra-red sensor scanning system located in a plane.

Two years of background data were obtained prior to Units 1 and 2 becoming operational. These data and the subsequent three years of data collected after the plant went operational are described in detail in Appendix M.

FIGURE 6: TEMPERATURE MONITORING RECORDERS - JAMES RIVER IN VICINITY OF HOG POINT

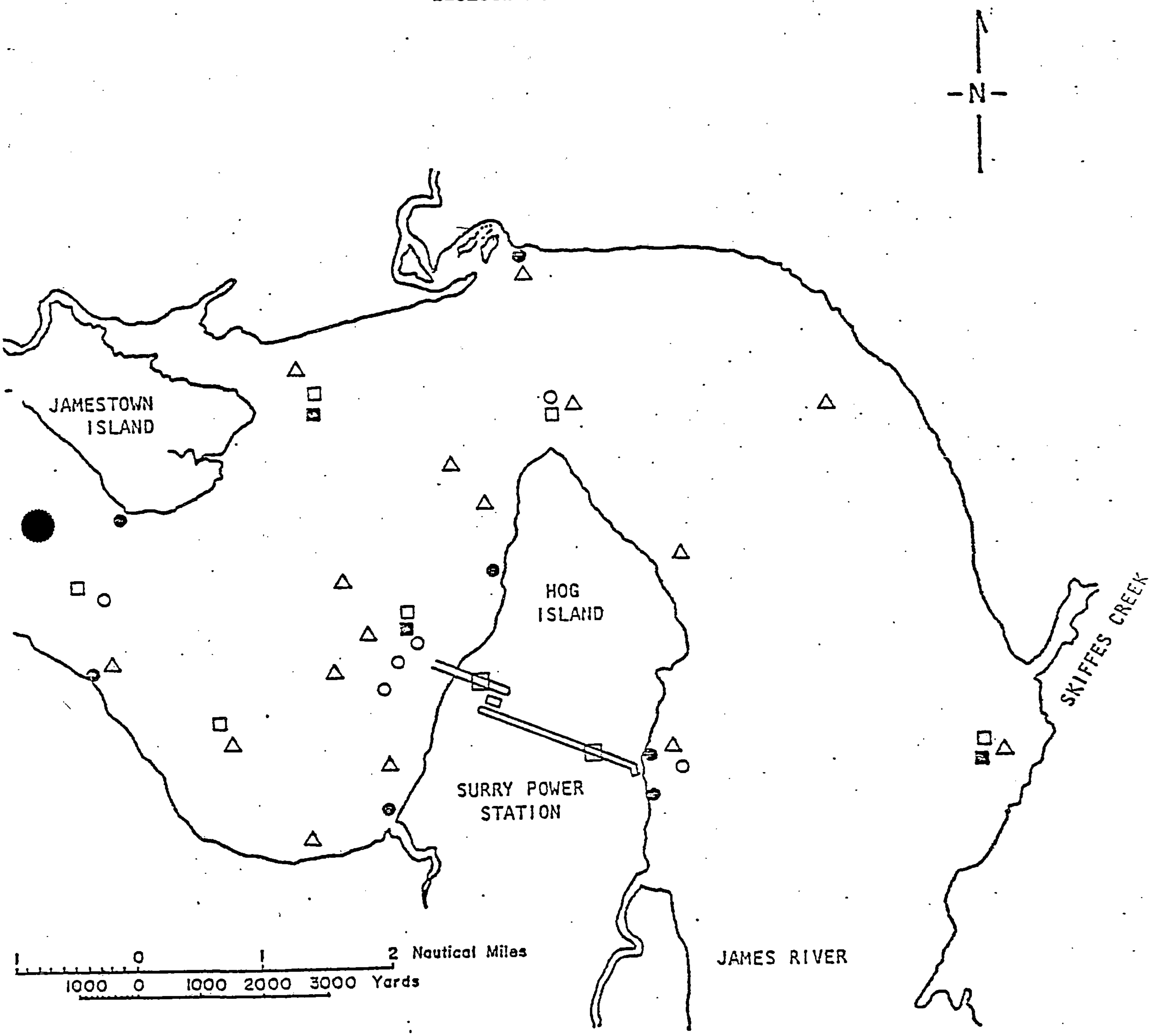


Legend
1. Station Intakes
2. Deepwater Shoals
3. Hog Point South
4. Hog Point North
5. Cobham Bay South
6. Cobham Bay Middle
7. Cobham Bay North
8. Jamestown Island

B. ECOLOGICAL FIELD STUDIES

Field studies designed specifically to characterize the biota in the Hog Point region of the James River were originated in May, 1969 by VIMS and by Vepco in 1970. The field work placed primary emphasis on fish populations and benthic communities but also included studies on phytoplankton, zooplankton, and fouling organisms. Figure 7 locates the sampling stations for various components of the Surry Power Station ecological studies.

BIOLOGICAL SAMPLE STATIONS



- ○ Trawl (Nekton)
- ● Seine (Nekton)
- □ Plankton
- ▣ Fouling Plates
- △ Benthos

FIGURE 7: Sample station locations for various components of the Surry Power Station ecological studies.

1. Finfish

A program by Vepco personnel was begun in May, 1970, to identify finfish populations in the shallow water oligohaline zone of the James River near the Surry Power Station. The program's purpose was to obtain baseline data prior to the facility becoming operational. Collections were taken monthly by beach seine and by otter trawl at thirteen locations. In addition, fish populations have been sampled by VIMS Ichthyological Department on a monthly basis at four locations in the James River near Surry since 1964. These data collectively provided a sound data base to which similar post-operative study results could be compared (Appendices N, O, and E).

The postoperative studies were intensified to have a better understanding of the composition and changes of the fish populations at Surry. In addition to the haul seine and otter trawl samples, the circulating water intake screens were employed as a biological sampling gear type during this study. The circulating water intake screen system was sampled, usually five days per week, from July, 1972 through August, 1976 (Appendix O).

2. Benthos

Studies began in May, 1969, to quantitatively and qualitatively describe the benthic organisms found in the James River adjacent to the Surry Power Station. Samples were gathered quarterly with the exception of the summer months when samples were collected monthly. Two replicates were collected with a 0.07 m^2 Van Veen grab, washed through a 1 mm screen and preserved. Selection of the sixteen stations generally was based on the sediment type found at each station as well as on the areas most likely to be influenced by the thermal discharge. A large number of these stations were, therefore, concentrated in Cobham Bay, however, some were selected in areas not likely to be affected by the effluent (Appendices H and P).

3. Fouling Organisms

Fouling organism studies have been conducted at three river towers, Cobham Bay North, Cobham Bay South and Deep Water Shoals (Fig. 6), since 1971. The studies involved suspending two pairs of 125 x 75 mm asbestos plates one meter above the bottom at each of the towers, one pair being replaced monthly and the other on a yearly schedule. Scheduled plate removal and replacement have yielded data on the fouling community in this area (Appendix H).

4. Zooplankton

Surface zooplankton samples have been taken with a No. 20 mesh Clarke-Bumpass plankton sampler on a monthly schedule since November, 1972. Tow duration ranged from one minute to five minutes, depending on the turbidity conditions encountered. Samples were preserved and counts and identifications made using a dissecting microscope. Seven river stations were sampled in 1972-1974, increasing to twelve stations in 1975, while ten stations were sampled in 1976 (Appendices H and P).

5. Phytoplankton

Phytoplankton samples were taken monthly at seven river stations and in the intake and discharge canals in 1973 and 1974, and continued at six stations in 1975 and ten stations in 1976. A non-metallic 2-liter Van Dorn bottle was used for the collection. These samples were preserved with Lugols' iodine solution, and total cell counts and identification of dominant organisms were made using the inverted microscope method. These stations were also sampled and analyzed qualitatively in the second half of 1972. Monthly phytoplankton studies are continuing at ten stations. Chlorophyll $\bar{a}$ measurements were taken from July, 1972 through December, 1973 and again in 1975 and 1976. Primary productivity measurements have been taken at three stations monthly between May, 1971 and April, 1972. This program was continued in 1975. A modified C-14 procedure was utilized at river towers Cobham Bay North (CBN), Cobham Bay South (CBS) and at the intake canal (Fig. 6), (Appendices H and P).

C. ECOLOGICAL LABORATORY INVESTIGATIONS

Diaz (1972) studied the effects of thermal shock on growth, mortality and setting success of oyster larvae, Crassostrea virginica. Another study researched the reproductive cycle and larval tolerance of the brackish water clam, Rangia cuneata in the James River (Cain, 1972). Dressel (1971) examined the effects of thermal shock and chlorine exposure on the estuarine copepod, Acartia tonsa. Details of these studies are presented in Appendix I.

VIII. ANALYSIS OF SURRY STUDIES BY OAK RIDGE NATIONAL LABORATORY

The Oak Ridge National Laboratory, acting under contract with the Nuclear Regulatory Commission, reviewed the physical and biological data collected under the NRC Technical Specification requirements and published two reports authored by Adams, et al. on its evaluation of the non-radiological environmental technical specifications. The first, ORNL/NUREG/TM-69, Vol. 1, compared the quality of the studies conducted at eight nuclear powered generating facilities. The Surry studies received an overall ranking of 2, only behind Peach Bottom, a station located on a riverine impoundment. The authors acknowledged the quality of study data despite the complexity and dynamics of the tidal system at Surry.

A second report, ORNL/NUREG/TM-70, (Vol. 2 of ORNL/NUREG/TM-69), covered only the studies conducted over a three-year period at Surry.

The authors concluded that the data indicated that the thermal discharges were enhancing the nektonic (fish) and benthic populations in the discharge area, but were having a negative effect on the phytoplankton and zooplankton in the discharge area. However, they did not address the materiality of their interpretation of negative effects on phytoplankton and zooplankton, except insofar as their conclusions implicitly recognized that any such effects have not adversely affected nektonic or benthic populations.

The conclusions relating to adverse impacts were strongly challenged by aquatic scientists of the Virginia Institute of Marine Science and the Virginia Electric and Power Company. The Institute and the Company immediately requested the Oak Ridge National Laboratory to recall the publication and correct the erroneous data analyses that led to the conclusions. The Oak Ridge National Laboratory has not responded to the request.

The fish and benthic data reviewed by the authors were very straight-forward, and persons with minimal knowledge and experience in estuarine systems could only conclude that the thermal discharges were not adversely affecting the populations. The oligohaline-freshwater reach of an estuary is a very complex environment for phytoplankton and zooplankton, however, and the authors completely misinterpreted the data in arriving at their conclusions.

The authors major interpretive error resulted from their complete disregard for salinity differences that occur in an oligohaline reach of an estuary both within and between years. Salinity changes may also be associated with turbidity levels in this reach because high freshwater runoff which depresses salinity also carries high levels of suspended solids. Nektonic and benthic populations that are found in the area are much better adapted to cope with fluctuations in salinity and turbidity than are phyto- and zooplankton populations.

Dr. Robert A. Jordan, Associate Marine Scientist, Virginia Institute of Marine Science, was the scientist in charge of the phytoplankton and zooplankton studies. Dr. Jordan reviewed the Oak Ridge National Laboratory Report and submitted a critical review to the authors in support of the request to recall the publication.

Dr. Jordan pointed out that, "most of the data analyses performed by Adams, et al. in the sections listed above failed to support their conclusions, because the analyses either were fundamentally improper or were inaccurately done."

Dr. Jordan went on to say, "Consequently the statements made by Adams, et al. concerning the ecological impact of the Surry Power Plant are unjustified."

Adams, et al. concluded that the 1974 data suggested inhibition of phytoplankton production in the discharge area. Dr. Jordan replied, " . . . the 1974 control means lie within the discharge confidence limits for eleven of the twelve sampling dates. The control values and the discharge means were very close for the warm summer months of July, August, and September. There is certainly no statistical evidence for inhibition of phytoplankton production."

Adams, et al. contended that zooplankton densities at the control station were generally higher than those in the discharge area. Dr. Jordan's statistical analysis of the data for 1975 indicated that only two t values were significant, the value for May when the discharge mean was significantly higher than the mean for the control station and the value for July when the control mean was higher. He concluded, "These test results certainly do not support the author's statement."

The Conclusion section of Dr. Jordan's critical review follows:

> "The deficiencies present in the data evaluations performed by Adams et al. are serious. The authors committed many errors attributable to carelessness: improper application of the log transformation; inaccurate construction of graphs; inaccurate interpretation of graphs. Other errors may be attributable to ignorance: failure to select benthos stations with the same substrate type to use in their data comparisons; selection of a study conducted in the polyhaline York River to provide the basis for predicting plankton responses to a thermal effluent in the oligohaline James River. Their most serious technical error, however, which renders all of their conclusions invalid, is their complete failure to invoke the concept of statistical significance in making the comparisons upon which their conclusions are based. Professional scientists cannot be forgiven for such a failure. As I mentioned in the section on models,

I suspect that the preoccupation of Adams et al. with performing a modeling exercise can explain, to a large degree, their approach to the data evaluation and their zeal to demonstrate power plant effects that, upon proper scrutiny, prove to be imaginary."

Staff members of the Virginia Institute of Marine Science have presented numerous papers at professional meetings (Atlantic Estuarine Research Society, National Benthological Society, etc.) which described the flora and fauna of the James River in the vicinity of Hog Point before and/or after the operation of Surry Units 1 and 2. Without exception, these papers reached the same conclusion as that contained in this demonstration - that the operation of the Surry Power Station was not adversely affecting the balanced, indigenous aquatic populations of the James River.

In summary, while the Oak Ridge review of existing data concluded that the data indicated a reduction in planktonic populations in the immediate discharge area but enhancement of benthic and nektonic populations, intensive and extensive studies conducted by the Virginia Institute of Marine Science and Vepco discussed in this demonstration, indicate that the thermal effluent from the Surry Power Station is not adversely affecting any trophic level including the balanced, indigenous population of fish, shellfish, or wildlife in the James River.

IX. THERMAL PLUME ANALYSIS

A. PHYSICAL MODEL PREDICTIONS

The distribution of excess temperature that would result from the discharge of waste heat from the Surry Power Station was determined from studies conducted on the hydraulic model of the James River estuary located at the U. S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi. This physical model covers the entire tidal waterway from Richmond to the mouth, and part of the lower Chesapeake Bay. Studies were conducted for Vepco by Pritchard-Carpenter, Consultants and are appended as Appendix L. The model has a horizontal scale of 1:1000, and a vertical scale of 1:100. The approximately 90 nautical miles of the estuary are therefore represented by a model about 550 feet long. The time scale of this model is 1:100; therefore one day in the prototype occurs in about 14 1/2 minutes in the model.

All pertinent features of tide, current, river inflow, and mixing of seawater and freshwater are properly scaled in the model. Density, temperature, and salinity are all scaled 1:1 in this model, and previous studies have shown that for models of this relative size, the thermal exchange processes at the water surface are also properly scaled.

A model heat source was constructed at the site of the Surry Power Station on the James River estuary. The heat source was designed to maintain a constant temperature rise of 15 F between the intake and discharge.

Tests were conducted during two different periods. The first set of tests were made between 29 July - 1 August 1966, and the second series during the period 19 October - 23 October 1966. The freshwater inflow at Richmond was maintained throughout the first series at a simulated 2000 cfs. The results of the first series of tests determined that the ideal discharge of the heated effluent back to the James River could be accomplished through a six foot per second discharge velocity.

For the second series improvements were made in the temperature measuring system so that 2 thermister bead sensors were towed across the model on each run. In the October series the model was run for a total of 784 tidal cycles, corresponding to about 379 days of prototype time.

In addition to the simulated flow of 2000 cfs from Richmond into the model, tests were also run simulating a river flow of 6000 cfs. Results showed that there was very little difference in the distribution of excess temperature under these two different river flows. This lack of difference is largely attributable to the initial mechanical mixing produced by the jet discharge, which provides for a rapid decrease in the maximum excess temperatures. In addition, mixing provided by the oscillatory ebb and flood of the tide, which on a single flood tide passes an average of 190,000 cfs pass the plant site, is not significantly influenced by river discharge except during very high river flows.

The results of the thermal studies in the James River estuarine model show that only a small portion of the estuarine water in the tidal segment adjacent to the plant site would be subject to excess temperatures which might have biological significance, assuming that the plant were designed, built and operated according to the parameters tested in the model. Averaged over a tidal cycle the area having excess temperatures exceeding 5 C would occupy less than 7 percent of the width of the estuary. Over 2/3 of the width of the estuary in the tidal segment adjacent to the discharge would have excess temperatures less than 2 C. The highest excess temperature which completely encloses cross-section of the river would be 0.80 C which occurs at only 1 of the eight distributions over the tidal cycle. The average closing excess temperature over the tidal period would be 0.66 C.

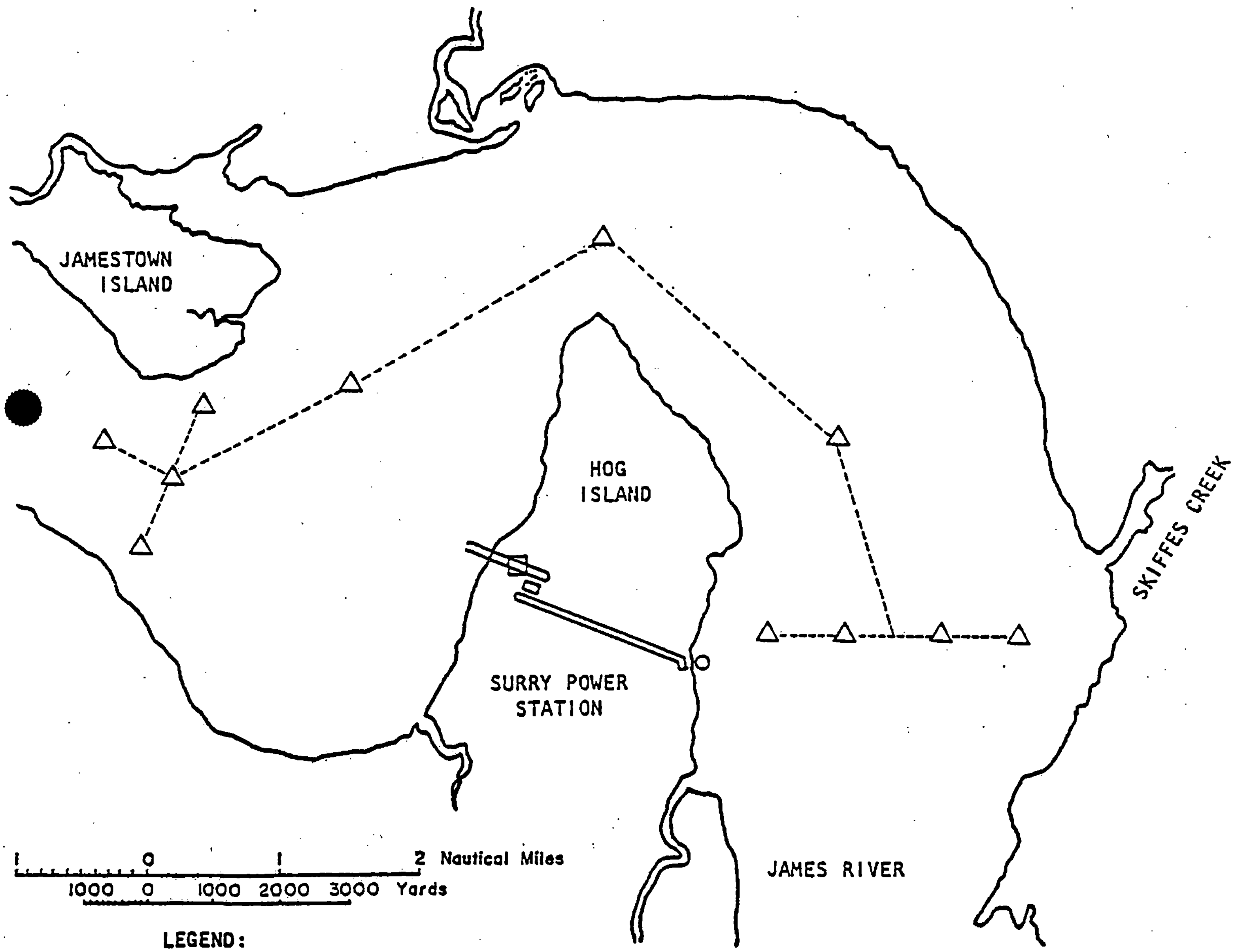
Other results of the model study indicated parameters that might be useful in the design and construction of the Surry Power Station. For example, it was found that the condenser cooling water circulating system with an intake on the downstream side of the site and the discharge on the upstream side would be more desirable from the standpoint of the estuarine environment than the opposite arrangement. In addition, the mechanical mixing produced by a jet discharge, and the turbulent mixing resulting from the tidal currents, should contribute significantly to reducing the area occupied by the warmest water. Subsequently, these two parameters in particular were incorporated into the design of Surry Power Station.

For a more detailed study of the results of the model test, the reader is referred to Appendix L.

B. FIELD MEASUREMENTS

Temperature distribution in the James River in the vicinity of Surry Power Station is measured by two methods: stationary recorders affixed to towers or buoys within the river (Fig. 6), and a monthly boat survey that starts downstream near the intake at low slack water and proceeds upstream to the vicinity of Jamestown Island (Fig. 8). In addition, the Virginia Institute of Marine Science, under a grant from the Nuclear Regulatory Commission, conducted a multitude of near-field measurements during several years of station operation (Appendix M).

Results generally show that the thermal plume dissipates rapidly due to the proper functioning of the jet discharge at the end of the discharge groin. Rapid mixing occurs between the heated effluent and ambient river water causing the area of excess temperature to be kept at a minimum.



LEGEND:

△ Monthly Salinity - Temperature Profile Station

○ Continuous Salinity - Temperature Monitoring Station

□ Near Surface Temperature Monitoring Station

---- Boat Cruise

FIGURE 8: Boat cruise temperature and salinity monitoring stations.

C. COMPARISON OF FIELD DATA WITH MODEL PREDICTIONS

Although Vepco has been collecting monthly temperature and salinity data as well as continuous temperature and salinity data from the James River estuary in the vicinity of the Surry Power Station, probably the most intensive survey in the area has been conducted by Dr. C. S. Fang, Virginia Institute of Marine Science, under ERDA project AT-(40-1)-4067. Results of Dr. Fang's study may be found as Appendix M.

Comparison of actual field studies with model studies indicates that model results tend to be about an order of magnitude higher in their predictions than actual field measurements. The main reason for this discrepancy lies in the fact that the scale of the model is distorted and does not appear to accurately predict water entrainment and near field excess temperatures. Because actual field data show that the areas of excess temperature are much less than the model predicted, and therefore much of the James River in the area is not affected by the thermal plume from Surry Power Station, the reader is referred to Appendix M showing six parts of the study by Dr. Fang on "The Thermal Effects of the Surry Nuclear Power on the James River, Virginia."

D. COMPLIANCE WITH WATER QUALITY STANDARDS

The Commonwealth of Virginia has determined that the thermal discharge from Surry Power Station is in compliance with state water quality standards. This determination will be reflected in the amended NPDES permit.

X. THERMAL EFFECTS

The following section contains information from studies conducted over the past seven years (1970-1976) which show, in keeping with the purpose of the Type I demonstration (absence of prior appreciable harm), that the Surry Power Station has been operated for five years with no appreciable harm occurring in the balanced indigenous populations of fish, shellfish, and wildlife in the James River estuary surrounding the Surry Power Station. Sample station locations for various components of the study are shown on Figure 7.

A. FINFISH

Vepco has elected to examine fish populations in the Surry area through the study of juvenile fishes. This stage in the life cycle is usually beyond the stages of highest natural mortality and can be used to reflect the general success and "health" of the current year-class of any given species as well as to make implications concerning past and future adult populations. In addition, juvenile fishes are more susceptible to capture by present-day biological sampling gear than are larvae or adults. Fishes less than 30 mm TL and greater than 200 mm TL usually display gear avoidance behavior patterns not so commonly found in fishes within this size range. Finfish in the oligohaline zone of the James River have been examined with probably more intensity and repetitiveness than lower organisms since the ecological "health" of this trophic level generally reflects the "health" of the ecosystem as a whole. The breakdown of, or damage to, a lesser trophic level should manifest itself in this higher level once or twice removed from the affected component.

The studies of fish populations influenced by Surry Power Station operations commenced in May, 1970, and have concentrated on a 10-mile stretch of the James River centered on Hog Island (Appendices N and O). This geographical limit allowed for a characterization of populations found about 5 miles upstream and downstream from Hog Point and encompassed both the intake and discharge areas as well as the primary study area and a reasonable far-field study area. In addition to the study of juvenile fishes by Vepco, fish eggs and larvae of the area have been sampled by VIMS through a thermal plume entrainment study (Appendices H and P).

Although estuaries are generally regarded as intricate environments their transition zones display an even greater complexity with wide variability being characteristically normal. Physico-chemical parameters such as temperature and salinity exhibit wide annual ranges and are subject to rapid changes within each range. Variations in freshwater input from the basin watershed, in addition to tidal fluctuations, have a pronounced influence on these parameters. Natural events such as floods, hurricanes, and droughts are added variables. These changes continually influence freshwater, estuarine, and marine fishes which perpetually immigrate and emigrate through the area at different life stages. In addition, natural or man-made occurrences may be causative factors of periodic fish kills which, in turn, influence the relative abundance and/or behavior of certain species.

In an effort to assess the composition and fluctuations of the fish populations as influenced by thermal and other factors, haul seines, trawls, and circulating water system intake screen were used during this study. While each gear type has its own limitations, their uses in a repetitive sampling program have collectively provided the best available insight into the composition, habits, and movements of young fishes in the area.

The overall program was divided into three parts. Seines at seven stations and trawls at six stations (Fig. 9) were used in a monthly pre-operational and postoperational survey (May, 1970 - August, 1976) (Appendix 0) and are continuing. A haul seine was used to study shore zone populations at three stations (Fig. 10) between the power station intake and discharge points (hereinafter called the special seine program). These three stations were sampled from May, 1973 through August, 1976. The circulating water system intake screens were sampled for impinged fish, usually five days a week, from July, 1972 through August, 1976.

Results from these three studies covering the period from May, 1970 through August, 1976 have been presented in an inclusive report (Appendix 0).

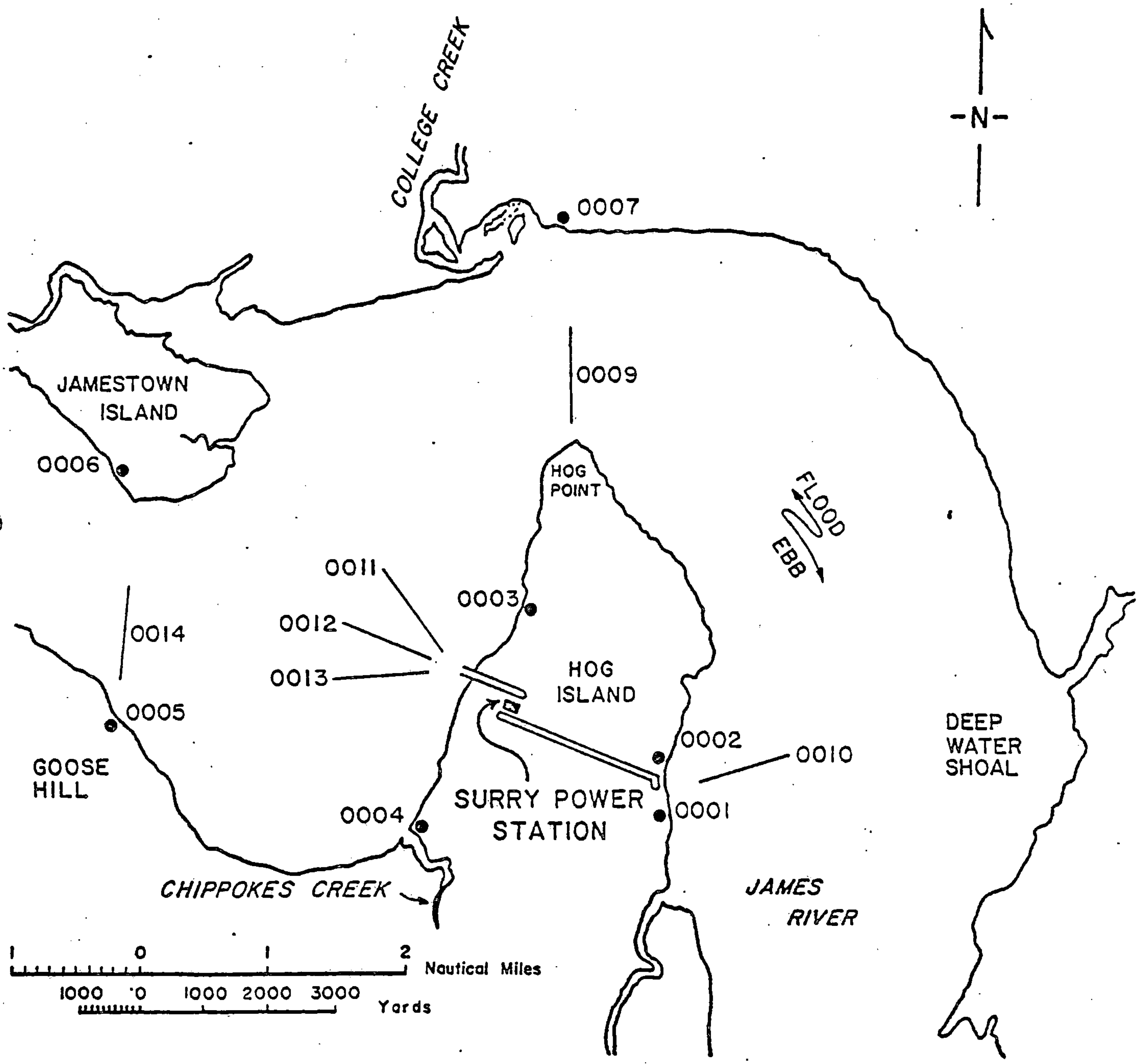
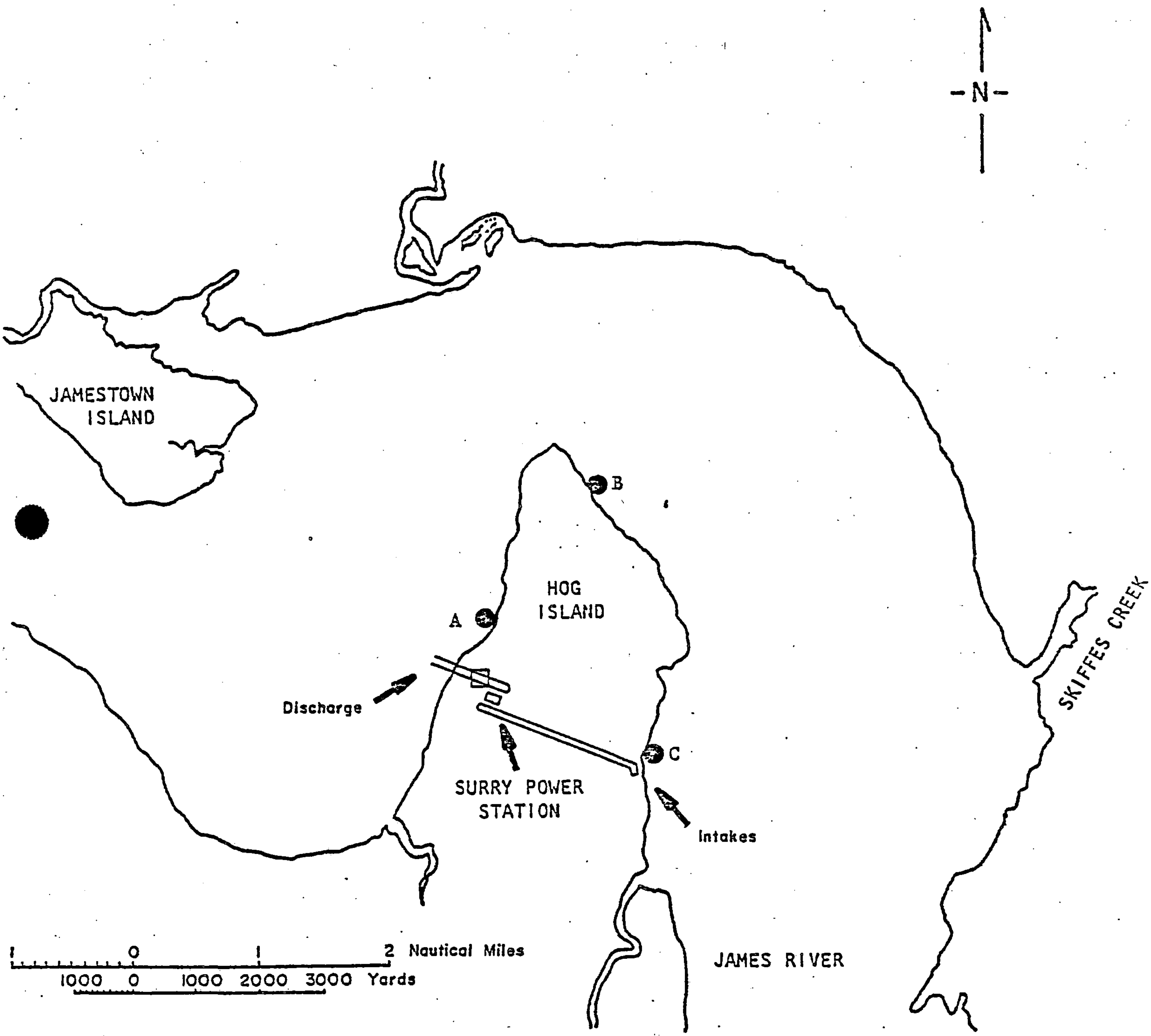


FIGURE 9: Sample stations for haul seine and otter trawl.
Haul seine - 0001 to 0007; otter trawl - 0009 to 0014.



A—Hog Point-West
B—Hog Point-North
C—Hog Point-East

FIGURE 10: Sample stations for special seine study.

Using three gear types during the six years of the study, 84 species and five genera of fishes were collected. This diverse population included 32 freshwater species, 32 species living in both the Atlantic Ocean and freshwater, and 20 species normally inhabiting only the Atlantic Ocean. The following are the major conclusions resulting from this comprehensive examination of young fishes residing in that section of the James River most likely to be influenced by operation of the Surry Power Station.

This series of studies has shown that the nektonic community around Surry is very diverse and dynamic, changing monthly and seasonally between species and sizes of individuals within species (Fig. 11). Diversity, evenness, and richness indices are useful analyses for determining long-term community trends and comparing pre- and postoperational communities. Since wide variability exists within and between samples, fish communities were analyzed by season, e.g., a given diversity for a given seine or trawl gear type for a given season is representative of samples from seven collection sites taken once each month for three months. Data pooled in this manner provide a more realistic look at fish community changes and provide a damping effect on the within and between station variability.

The diversity, evenness, and richness trends are amenable to a parametric test such as regression analysis. Using least squares regression, analyses show that the young fish populations around Surry have remained relatively stable for the past six years (including two years preoperational and four years postoperational data). Regression slopes have either: (1) not changed significantly, or (2) increased slightly ($p < 0.05$) over time indicating improvement.

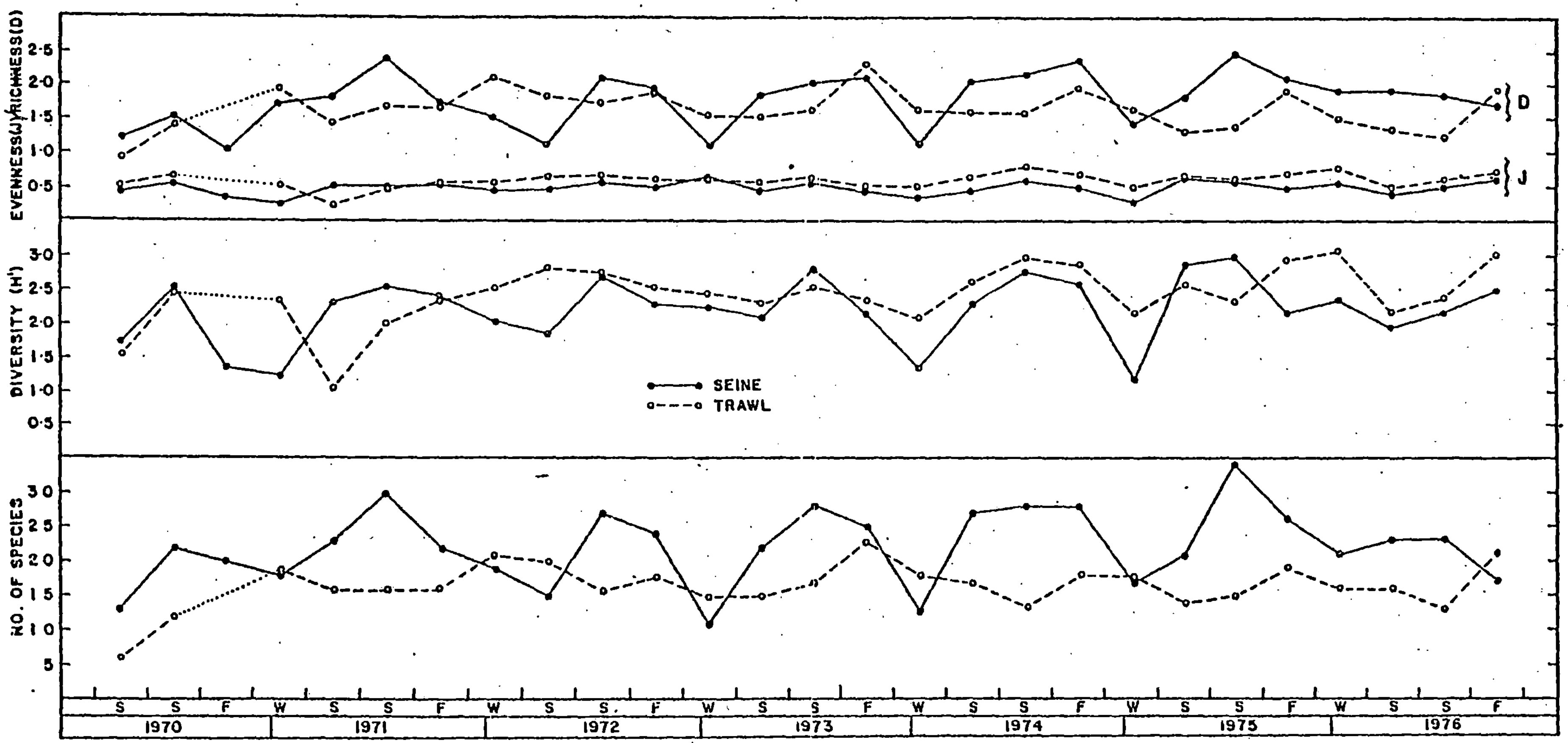


FIGURE 11: Number of species, diversity (H'), evenness (J), and richness (D) by season for seine and trawl caught fishes, 1970-1976.

A non-parametric comparison between preoperational and postoperational diversity indices indicated either no significant difference in the means or that preoperational means were significantly ($p < 0.05$) less than postoperational means. The null hypothesis was that the preoperational mean and postoperational mean were equal.

It was therefore concluded not only but from both parametric and non-parametric analyses of the data in Figure 11, that operation of the Surry Power Station has caused no appreciable harm to the fish community in the area. A negative response, if any, of the young fish community has not been evident as community diversity, evenness, and richness indicators have remained relatively stable or increased slightly during the six years of the study (Fig. 11).

At the species level, the following discussion focuses on the dominants, as well as certain non-dominant commercially and recreationally important species. Changes have taken place at the species level within the community that are a direct response to other environmental perturbations that have occurred in the James River. During the study period from May, 1970 through August, 1976, a major hurricane (Agnes) resulted in the flood of record and corresponding salinity depression; several other floods occurred; droughts and attendant salinity elevations were frequent; rainfall patterns within any given year did not appear to follow expected "norms"; winters were relatively mild, on the average, except for an occasional cold snap, similar to that in January, 1976, that caused water temperatures to drop sharply in a relatively short period of time.

Between 1962 and 1971, there were 17 documented fish kills in the James River between Hopewell and Jamestown (Appendix O). The Virginia Water Control Board lists 24 kills in the lower James River alone from 1962 to 1973

(Appendix Q). The kill of 1971, prior to Surry operations, was one of the worst on record and possibly contributed to the precipitous population decline experienced by white perch, Morone americana. Other species possibly affected included striped bass (Morone saxatilis) and hogchoker (Trinectes maculatus). Another kill was recorded in 1973, and another in 1974. No kills, however, were associated with the operation of the Surry Power Station.

These events have undoubtedly influenced specific fish populations in the James River. The response of the individual species, however, has not always been one of population decline (Tables 5, 6, 7). Marine spawners whose larvae and young use the river as a nursery have generally shown increases in relative abundance. Atlantic menhaden (Brevoortia tyrannus), spot (Leiostomus xanthurus), and Atlantic croaker (Micropogon undulatus) are three of the dominants at Surry that were spawned in the marine environment. Using a combination of seine and trawl catches, these three species have shown increases over preoperational times in relative percent of the total number of fishes taken during operational times. Declines in relative abundance of some anadromous species such as alewife (A. pseudoharengus) and blueback herring (A. aestivalis) have been attributed by VIMS to natural fluctuations in year-class strength and offshore catches by foreign fishing fleets (Appendix E). Estuarine species such as the indigenous bay anchovy (Anchoa mitchilli) and silversides (Menidia spp.) have shown no change at all or have increased. Upper estuarine species such as channel catfish (Ictalurus punctatus) and spottail shiner (Notropis hudsonius) have experienced significant population increases.

The results of all of these studies only serve to emphasize what is already known about young fish populations in the transition zone of an estuarine environment. While this zone serves as a nursery for some species, there is

TABLE 5 -PREOPERATIONAL AND POSTOPERATIONAL HAUL SEINE DATA

Pre - 149 hauls
Post - 357 hauls

Frequency of Occurrence (%)

	Pre	Post
Silverside sp.	95	99
Spottail Shiner	57	77
Bay Anchovy	56	53
White Perch	41	10
Blueback Herring	39	39
Mummichog	28	17
Spot	28	30
Striped Bass	24	2
American Shad	22	8
Atlantic Menhaden	22	21
Gizzard Shad	20	23
Golden Shiner	18	37
Pumpkinseed	13	13
Alewife	11	7
Hogchoker	11	4
Hickory Shad	10	≤1
Atlantic Needlefish	9	T
American Eel	7	4
Yellow Perch	7	4
Channel Catfish	6	15
Striped Killifish	5	≤1
Brown Bullhead	5	6
Banded Killifish	5	27
Atlantic Croaker	4	13
Bridle Shiner	3	1
Weakfish	3	0
Crevalle Jack	2	0
Naked Goby	2	1
Sunfish sp.	2	≤1
Largemouth Bass	2	0
Darter sp.	≤1	2
Eastern Mudminnow	≤1	0

	Pre	Post
Carp	≤1	3
Summer Flounder	≤1	4
Mosquitofish	≤1	2
Tessellated Darter	≤1	1
White Catfish	≤1	2
Silver Perch	≤1	0
Bluefish	≤1	1
Harvestfish	≤1	0
Bluegill	≤1	1
Common Shiner	0	6
Threadfin Shad	0	7
Satinfin Shiner	0	13
Silvery Minnow	0	8
Johnny Darter	0	2
Shiner sp.	0	1
Striped Mullet	0	5
Rough Silverside	0	3
Chain Pickerel	0	≤1
Ladyfish	0	2
Bonefish	0	≤1
Sheepshead Minnow	0	≤1
Bluespotted Sunfish	0	≤1
Redfin Pickerel	0	≤1
Smallmouth Bass	0	≤1
White Mullet	0	1
Spotfin Killifish	0	≤1
Longnose Gar	0	≤1
Redbreast Sunfish	0	≤1
Shorthead Redhorse	0	≤1
Ironcolor Shiner	0	≤1

TABLE 6 -- PREOPERATIONAL AND POSTOPERATIONAL HAUL SEINE DATA

Pre - 149 hauls
Post - 357 hauls

Total Number (%)

	Pre	Post		Pre	Post
Blueback Herring	18.6	15.5	Naked Goby	≤0.1	≤0.1
Silverside sp.	18.0	24.5	Bluegill	≤0.1	≤0.1
Atlantic Menhaden	16.3	21.2	Bluefish	≤0.1	≤0.1
Bay Anchovy	14.8	9.9	Silver Perch	≤0.1	0
Alewife	8.5	0.4	Largemouth Bass	≤0.1	0
Spot	6.6	2.2	Weakfish	≤0.1	0
White Perch	4.2	0.5	Harvestfish	≤0.1	0
American Shad	4.2	1.3	Eastern Mudminnow	≤0.1	0
Spottail Shiner	3.8	15.1	Crevalle Jack	≤0.1	0
Striped Bass	1.6	0.1	Striped Mullet	0	≤0.1
Mummichog	0.9	1.1	Common Shiner	0	0.2
Atlantic Needlefish	0.8	≤0.1	Rough Silverside	0	≤0.1
Golden Shiner	0.5	1.9	Threadfin Shad	0	0.2
Hickory Shad	0.3	≤0.1	Satinfin Shiner	0	0.2
Hogchoker	0.2	≤0.1	Silvery Minnow	0	0.3
Gizzard Shad	≤0.1	0.4	Johnny Darter	0	≤0.1
Brown Bullhead	≤0.1	≤0.1	Chain Pickerel	0	≤0.1
Pumpkinseed	≤0.1	0.2	Ladyfish	0	≤0.1
Sunfish sp.	≤0.1	≤0.1	Shiner sp.	0	≤0.1
Channel Catfish	≤0.1	0.5	Spotfin Killifish	0	≤0.1
Yellow Perch	≤0.1	≤0.1	White Mullet	0	≤0.1
Striped Killifish	≤0.1	≤0.1	Smallmouth Bass	0	≤0.1
American Eel	≤0.1	≤0.1	Redfin Pickerel	0	≤0.1
Atlantic Croaker	≤0.1	0.7	Bluespotted Sunfish	0	≤0.1
Banded Killifish	≤0.1	3.1	Sheepshead Minnow	0	≤0.1
Darter sp.	≤0.1	≤0.1	Bonefish	0	≤0.1
Carp	≤0.1	≤0.1	Redbreast Sunfish	0	≤0.1
Summer Flounder	≤0.1	≤0.1	Ironcolor Shiner	0	≤0.1
Bridle Shiner	≤0.1	≤0.1	Shorthead Redhorse	0	≤0.1
White Catfish	≤0.1	≤0.1	Longnose Gar	0	≤0.1
Mosquitofish	≤0.1	≤0.1			
Tessellated Darter	≤0.1	≤0.1			

TABLE 7 -- PREOPERATIONAL AND POSTOPERATIONAL TRAWL DATA

Pre - 90 trawls
Post - 300 trawls

Frequency of Occurrence (%)

	Pre	Post
Hogchoker	84	50
White Perch	56	25
Channel Catfish	53	74
White Catfish	46	55
Bay Anchovy	39	48
Spot	34	40
Atlantic Croaker	34	44
Spottail Shiner	29	39
Brown Bullhead	26	4
American Eel	22	22
American Shad	18	8
Alewife	17	16
Carp	16	14
Weakfish	16	4
Striped Bass	16	2
Blueback Herring	12	9
Gizzard Shad	8	11
Silver Perch	6	1
Darter sp.	6	1
Pumpkinseed	6	5
Hickory Shad	4	0
Tessellated Darter	3	4
Crevalle Jack	3	1
Yellow Perch	3	1
Atlantic Sturgeon	2	0
Silverside sp.	2	1
Harvestfish	≤1	0
Seaboard Goby	≤1	1
Bluespotted Sunfish	≤1	0
Atlantic Menhaden	≤1	9
Summer Flounder	0	5
Threadfin Shad	0	12
Redbreast Sunfish	0	≤1
Longnose Gar	0	≤1
Ladyfish	0	≤1
Catfish sp.	0	≤1
Naked Goby	0	2
Spotfin Mojarra	0	≤1
Silvery Minnow	0	≤1
Spotted Hake	0	≤1
Bluefish	0	≤1

Total Number (%)

	Pre	Post
Hogchoker	46.1	11.7
Channel Catfish	8.8	22.9
Spot	8.4	18.1
White Perch	8.2	1.3
Atlantic Croaker	7.9	15.5
Bay Anchovy	5.0	9.5
White Catfish	3.1	4.9
Alewife	2.6	0.6
Spottail Shiner	2.6	5.3
American Shad	1.3	0.3
Brown Bullhead	1.1	≤0.1
Weakfish	0.8	0.2
Striped Bass	0.7	≤0.1
American Eel	0.7	1.0
Carp	0.5	0.4
Blueback Herring	0.4	0.5
Silver Perch	0.3	≤0.1
Gizzard Shad	0.3	0.7
Hickory Shad	0.2	0
Pumpkinseed	0.2	0.3
Crevalle Jack	≤0.1	≤0.1
Darter sp.	≤0.1	≤0.1
Tessellated Darter	≤0.1	0.2
Atlantic Sturgeon	≤0.1	0
Silverside sp.	≤0.1	≤0.1
Yellow Perch	≤0.1	≤0.1
Harvestfish	≤0.1	0
Seaboard Goby	≤0.1	≤0.1
Bluespotted Sunfish	≤0.1	0
Atlantic Menhaden	≤0.1	0.4
Summer Flounder	0	0.2
Threadfin Shad	0	5.4
Redbreast Sunfish	0	≤0.1
Longnose Gar	0	≤0.1
Ladyfish	0	≤0.1
Catfish sp.	0	≤0.1
Naked Goby	0	≤0.1
Spotfin Mojarra	0	≤0.1
Silvery Minnow	0	≤0.1
Spotted Hake	0	≤0.1
Bluefish	0	≤0.1

considerable immigration and emigration through the zone as well as constant changes taking place within the zone as well as without. Interspecific and intraspecific competition for food and space are commonplace. Over an extended time period, natural and man-made insults generally appear to result only in relatively short-term changes, and fishes within the zone apparently thrive.

These results also show that, despite numerous environmental perturbations occurring in almost every year of the studies, the young fish population in the transition zone of the James River has remained relatively diverse and stable.

Turning to ichthyoplankton, the transition zone supports little spawning activity although its nursery function has been established previously. Relatively few fish eggs and larvae are found in the area of Surry Power Station (Appendices H and P). Of those found, numbers of individuals and numbers of species are generally at their highest in early summer, declining during late summer and early fall. Although the number of species continues to decrease in late fall, total numbers of larvae increase. Wintertime sees fluctuating levels of, and early springtime shows increases in, both species and individuals within species.

Analysis of total catch data showed little or no entrainment of fish larvae or fish eggs by the thermal plume. VIMS concluded that effects on ichthyoplankters caused by Surry, if any, were within natural variability. Thus, the thermal effluent is resulting in no appreciable harm to the ichthyoplankton component of the nekton community of the James River. Naked goby, Gobiosoma bosci, and bay anchovy, Anchoa mitchilli, are the dominant species whose eggs (anchovy only) and larvae are found in the area. These two estuarine species have centers of abundance downstream from Surry Power

Station and those in the oligohaline zone are representative of the upstream edge of the population. Postlarvae and/or juveniles of some commercially important species such as Atlantic croaker, Micropogon undulatus, and spot, Leiostomus xanthurus, were captured seasonally in relatively low numbers; however, these are ubiquitous species, being widespread along the Atlantic and Gulf of Mexico coasts.

Species occurrences by temperature and salinity give some indication of the environmental limits within which these species were found during the course of the study (Tables 8, 9). It is interesting to note that both marine and freshwater species apparently tolerate lower and higher salinity levels, respectively, than is popularly believed.

An additional area of concern in more northern latitudes is one of "cold shock" whereby fish kills can occur upon rapid temperature decrease during winter months. No "cold shock" caused fish kills or other effects have been observed during Surry operations.

The thermal plume was not found to form a barrier to migratory fishes. This finding was confirmed by catches of several comparatively strong year-classes of juvenile blueback herring (Alosa aestivalis), the most numerically dominant of the James River anadromous fishes. These fishes had migrated as adults upstream past Surry to spawning grounds near Hopewell and Richmond and the young were sampled as they migrated downstream past Surry to Chesapeake Bay.

Several important conclusions can be drawn from the results of the finfish study:

1. Surry Power Station operations have had no significant effect on the young fish community of the James River.

2. From May, 1970 through August, 1976, several major environmental disturbances (Surry was not one) have occurred.

TABLE 8: Species Oc[illegible]rence by Temperature.

SP	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	COUNT
ACIPENSER OXYRHYNCHUS								X																	X											2
ALBULA VULPES																																			X	1
ALOSA AESTIVALIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			33
ALOSA MEDIOCRIS					X			X	X						X	X	X	X			X		X	X	X	X	X	X	X							15
ALOSA PSEUDOHARENGUS	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			32
ALOSA SAPIDISSIMA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					31
AMIA CALVA						X	X	X		X	X	X	X	X	X					X																10
ANCHOA HEPSETUS																									X				X		X					3
ANCHOA MITCHILLI			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			30
ANGUILLA ROSTRATA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			33
BAIRDIELLA CHRYSURA									X			X		X	X		X	X	X		X	X		X	X	X			X	X						14
BREVOORTIA TYRANNUS		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	34
CARANX HIPPOS											X					X		X	X	X	X		X	X	X	X	X	X	X				X			14
CENTRARCHUS MACROPTERUS													X																X							2
CITHARICHTHYS SPILOPTERUS																													X							1
CYNOSCION NEBULOSUS																X									X		X									3
CYNOSCION REGALIS						X	X			X	X				X	X		X	X	X	X	X	X	X	X	X	X	X	X	X		X				20
CYPRINIDAE					X					X																										2
CYPRINODON VARIEGATUS								X		X	X	X	X		X	X	X	X		X	X	X			X	X	X	X	X							17
CYPRINUS CARPIO		X	X	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			30
DOROSOMA CEPEDIANUM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	35
DOROSOMA PETENENSE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	34
ELOPS SAURUS								X		X			X	X		X			X	X	X	X				X	X	X	X	X	X	X	X			17
ENNEACANTHUS GLORIOSUS																		X		X					X	X	X	X	X							7
ERIMYZON SP.														X																						1
ESOX NIGER		X																									X									2
ETHEOSTOMA NIGRUM																									X	X			X	X	X		X			6
ETHEOSTOMA OLMSTEDI		X			X	X	X	X	X	X	X	X	X	X				X			X								X	X	X					16
ETHEOSTOMA SP.									X		X	X			X	X		X				X	X			X				X		X				11
EUCINOSTOMUS ARGENTEUS												X																								1
FUNDULUS CONFLUENTUS																										X										1
FUNDULUS DIAPHANUS		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	33
FUNDULUS HETEROCLITUS			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	32
FUNDULUS LUCIAE															X																					1
FUNDULUS MAJALIS				X				X			X		X		X										X		X		X	X	X					10
GAMBUSIA AFFINIS						X		X				X					X												X		X					6
GASTEROSTEUS ACULEATUS					X			X																												2
GOBIESOX STRUMOSUS																					X				X											2
GOBIOSOMA BOSCI					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				28
GOBIOSOMA GINSBURGI								X																												1
HYBOGNATHUS NUCHALIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					X	X	X	X	X	X	X	X		30
HYPORHAMPHUS UNIFASCIATUS																									X											1
ICTALURUS CATUS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	32
ICTALURUS NEBULOSUS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	34
ICTALURUS PUNCTATUS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	35
ICTALURUS SP.																													X	X						2
LEIOSTOMUS XANTHURUS			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	33
LEPISOSTEUS OSSEUS			X			X		X			X	X			X																X					7
LEPOMIS AURITUS														X	X					X		X				X		X		X						7
LEPOMIS GIBBOSUS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	34

TABLE 8 Cont'd

SP	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	COUNT
LEPOMIS GULOSUS													X																							1
LEPOMIS MACROCHIRUS								X		X	X		X	X	X		X		X	X	X		X	X		X	X	X								15
LEPOMIS SP.								X	X																		X	X	X	X						6
LUTJANUS GRISEUS																	X	X		X	X															4
MEMBRAS MARTINICA						X		X		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					23
MENIDIA BERYLLINA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	35
MENIDIA MENIDIA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	35
MENIDIA SP.				X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	30
MICROPOGON UNDULATUS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			33
MICROPTERUS DOLOMIEUI																X														X						2
MICROPTERUS SALMOIDES									X				X		X	X				X								X		X						7
MORONE AMERICANA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			33
MORONE SAXATILIS				X	X	X	X	X	X	X	X	X	X	X	X	X		X				X		X	X	X	X	X	X	X	X	X	X			25
MOXOSTOMA MACROLEPIDOTUM																															X					1
MUGIL CEPHALUS	X	X	X	X	X	X	X	X	X		X	X					X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	28
MUGIL CUREMA		X		X	X					X			X										X			X							X			8
NOTEMIGONUS CRYSOLEUCAS			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	32
NOTROPIS ANALOSTANUS								X	X	X	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X						21
NOTROPIS BIFRENATUS							X					X								X		X				X	X	X	X	X		X				10
NOTROPIS CHALYBAEUS																														X						1
NOTROPIS CORNUTUS								X		X	X		X			X				X	X	X	X			X	X		X	X		X	X			15
NOTROPIS HUDSONIUS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	35
NOTROPIS PROCNE																													X							1
NOTROPIS SP.												X				X													X	X						4
PARALICHTHYS DENTATUS							X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				24
PEPRILUS ALEPIDOTUS																			X	X		X	X	X	X	X	X	X	X							10
PEPRILUS TRIACNATHUS																									X											1
PERCA FLAVESCENS			X		X					X	X	X	X		X	X		X		X	X		X	X	X	X	X		X	X	X					19
PETROMYZON MARINUS											X		X	X	X	X	X				X	X														8
POMATOMUS SALTATRIX													X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X					18
POMOXIS NIGROMACULATUS														X	X				X							X										4
PRIONOTUS CAROLINUS																			X					X	X		X									4
PRIONOTUS TRIBULUS																												X								1
SCOMBEROMORUS MACULATUS																									X	X	X	X	X	X						6
SELENE VOMER																									X			X		X	X					4
SEMOTILUS ATROMACULATUS																											X									1
STRONGYLURA MARINA																		X	X						X	X	X	X	X	X	X	X				10
SYGNATHUS FLORIDAE															X																					1
SYMPHURUS PLAGIUSA						X		X		X					X		X	X	X																	7
TRICHIURUS LEPTURUS																								X			X									2
TRINECTES MACULATUS		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	31
UMBRA PYGMAEA				X																																1
UROPHYCIS REGIUS											X		X																							2

TABLE 9: Species Occurrence by Salinity

SP	0	PT5	1	2	3	4	5	6	7	8	9	10	11	12	COUNT
ACIPENSER OXYRHYNCHUS	X												X		2
ALOSA AESTIVALIS	X	X	X	X	X	X	X	X	X	X	X				11
ALOSA MEDIOCRIS	X	X	X	X	X	X	X		X	X					9
ALOSA PSEUDOHARENGUS	X	X	X	X	X	X	X	X	X	X	X	X			12
ALOSA SAPIDISSIMA	X	X	X	X	X	X	X	X	X	X	X				11
AMIA CALVA	X		X			X									3
ANCHOA HEPSETUS							X			X			X		3
ANCHOA MITCHILLI	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
ANGUILLA ROSTRATA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
BAIRDIELLA CHRYSURA			X	X	X	X	X		X	X	X	X		X	10
BREVOORTIA TYRANNUS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
CARANX HIPPOS	X	X	X	X	X	X	X	X		X	X	X	X	X	13
CENTRARCHUS MACROPTERUS	X														1
CITHARICHTHYS SPILOPTERUS								X							1
CYNOSCION NEBULOSUS					X				X		X				3
CYNOSCION REGALIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
CYPRINIDAE	X				X										2
CYPRINODON VARIEGATUS	X	X	X	X	X	X	X	X	X	X					10
CYPRINUS CARPIO	X	X	X	X	X	X	X	X	X	X	X	X			12
DOROSOMA CEPEDIANUM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
DOROSOMA PETENENSE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
ELOPS SAURUS	X		X	X	X	X	X	X	X	X	X	X	X	X	13
ENNEACANTHUS GLORIOSUS	X	X	X	X	X	X									6
ERIMYZON SP.	X														1
ESOX NIGER	X						X								2
ETHEOSTOMA NIGRUM			X	X		X	X	X							5
ETHEOSTOMA OLMSTEDI	X	X	X	X			X								5
ETHEOSTOMA SP.	X		X		X										3
EUCINOSTOMUS ARGENTEUS					X										1
FUNDULUS CONFLUENTUS		X													1
FUNDULUS DIAPHANUS	X	X	X	X	X	X	X	X	X	X					10
FUNDULUS HETEROCLITUS	X	X	X	X	X	X	X	X	X	X	X	X	X		13
FUNDULUS LUCIAE				X											1
FUNDULUS MAJALIS	X		X	X	X	X	X	X	X						8
GAMBUSIA AFFINIS	X		X		X	X									4
GASTEROSTEUS ACULEATUS			X												1
GOBIESOX STRUMOSUS												X			1
GOBIOSOMA BOSCI	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
GOBIOSOMA GINSBURGI				X											1
HYBOGNATHUS NUCHALIS	X	X	X	X	X	X	X	X	X	X					10
HYPORHAMPHUS UNIFASCIATUS													X		1
ICTALURUS CATUS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
ICTALURUS NEBULOSUS	X	X	X	X	X	X	X	X	X	X	X	X	X		13
ICTALURUS PUNCTATUS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
ICTALURUS SP.	X														1
LEIOSTOMUS XANTHURUS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
LEPISOSTEUS OSSEUS	X	X	X	X	X	X	X								7
LEPOMIS AURITUS	X	X	X	X	X				X						6
LEPOMIS GIBBOSUS	X	X	X	X	X	X	X	X	X	X	X	X	X		13
LEPOMIS GULOSUS	X														1
LEPOMIS MACROCHIRUS	X		X	X	X	X	X								6
LEPOMIS SP.	X		X	X	X		X								5
LUTJANUS GRISEUS	X	X	X	X	X										5
MEMBRAS MARTINICA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14

TABLE 9. Cont'd

SP	0	PT5	1	2	3	4	5	6	7	8	9	10	11	12	COUNT
MENIDIA BERYLLINA	X	X	X	X	X	X	X	X	X	X	X	X	X		13
MENIDIA MENIDIA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
MENIDIA SP.	X	X	X	X	X	X	X	X	X	X	X				11
MICROPOGON UNDULATUS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
MICROPTERUS DOLOMIEUI	X														1
MICROPTERUS SALMOIDES	X		X	X			X								4
MORONE AMERICANA	X	X	X	X	X	X	X	X	X	X	X	X	X		13
MORONE SAXATILIS	X	X	X	X	X	X	X	X	X		X		X	X	12
MOXOSTOMA MACROLEPIDOTUM	X														1
MUGIL CEPHALUS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
MUGIL CUREMA	X				X	X		X							4
NOTEMIGONUS CRYSOLEUCAS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
NOTROPIS ANALOSTANUS	X		X	X	X	X	X	X							7
NOTROPIS BIFRENATUS	X		X	X		X	X								5
NOTROPIS CHALYBAEUS	X														1
NOTROPIS CORNUTUS	X	X	X	X	X		X								6
NOTROPIS HUDSONIUS	X	X	X	X	X	X	X	X	X	X	X	X		X	13
NOTROPIS PROCNE				X											1
NOTROPIS SP.	X		X												2
PARALICHTHYS DENTATUS	X	X	X	X	X	X	X	X	X	X	X	X	X		13
PEPRILUS ALEPIDOTUS	X							X		X	X	X	X	X	7
PEPRILUS TRIACNATHUS										X					1
PERCA FLAVESCENS	X	X	X	X	X	X	X	X							8
PETROMYZON MARINUS	X	X	X	X											4
POMATOMUS SALTATRIX		X	X	X	X	X	X	X	X	X	X	X	X	X	13
POMOXIS NIGROMACULATUS	X		X	X											3
PRIONOTUS CAROLINUS					X								X	X	3
PRIONOTUS TRIBULUS							X								1
SCOMBEROMORUS MACULATUS					X	X	X	X	X			X	X	X	8
SELENE VOMER					X					X	X				3
SEMOTILUS ATROMACULATUS						X									1
STRONGYLURA MARINA	X		X	X	X	X	X	X	X	X	X	X	X		12
SYGNATHUS FLORIDAE			X												1
SYMPHURUS PLAGIUSA			X	X	X	X	X								5
TRICHIURUS LEPTURUS						X		X							2
TRINECTES MACULATUS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
UMBRA PYGMAEA								X							1
UROPHYCIS REGIUS						X					X				2

3. There have been increases in the relative abundance of some species, decreases in others, while still other species such as the indigenous bay anchovy have shown no change at all. None of these changes could be correlated with Surry operations.

4. No "cold shock" fish kills have occurred.

5. No thermal barrier to migratory fishes was found to be present.

6. These studies show that, despite both natural and man-made perturbations, the young fish community of the transition zone of the James River is viable and stable and, above all, exhibits no appreciable response to Surry Power Station operation.

B. BENTHOS

Benthic macroinvertebrate studies have been conducted in the transition zone of the James River since 1969. Because this zone is of low but highly variable salinity (Fig. 12) and is characterized by high turbidities and sedimentation rates, it presents an inhospitable environment for all but a few of the most tolerant of benthic species (Appendix G). Those surviving either maintain viable, reproducing resident populations, or are temporary invaders when suitable environmental conditions permit. Consequently, the benthos of the area are characterized by low species diversity values (0-3.04 bits per individual), values that have been found throughout the study period. Diversity values have remained within natural limits of level and variability before and during Surry Power Station operations which have had no detectable influence on the components of this trophic level (preoperational, 0-2.8; postoperational, 0-3.04).

As is typical of most zones of this type, a few species are overwhelmingly dominant. In the James River at Surry, the non-commercial brackish water clam, Rangia cuneata is found in abundance, and comprises more than 90% of the total invertebrate biomass. The American oyster (Crassostrea virginica) is not found in the oligohaline zone of the James River, this species being more mesohaline in habitat while the blue crab (Callinectes sapidus) is only a sporadic visitor to the Surry area. VIMS concluded that Rangia cuneata showed no obvious preference or avoidance regarding the thermal plume as increases and declines occurred at both plume and non-plume sampling stations. Rather, Rangia cuneata revealed an apparent preference for silty-clay substrates whether this substrate type was within the thermal plume area or not (Appendices H and P).

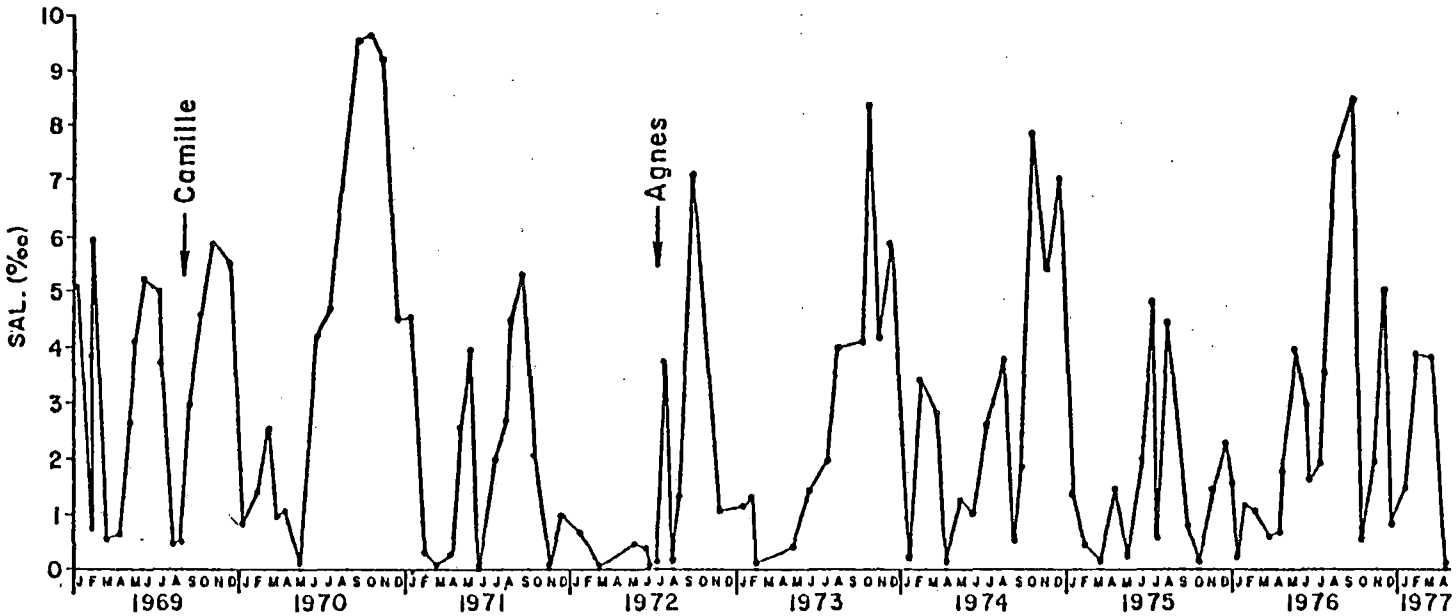


Figure 12: Temporal distribution of surface salinity at benthos Station 11. (from Appendix P)

Other benthic species have shown changes during operational times with some decreasing in abundance while others increased. These changes occurred at both plume and non-plume stations and appeared to be related to natural perturbations such as Hurricane Agnes and its attendant low salinity levels. These changes are reflected in species diversity levels as well as temporal distribution patterns (Appendices H and P).

Benthic macroinvertebrates represent an excellent example of the natural variability encountered in nature, the subtle as well as obvious changes that take place over time, and, above all, the resiliency of the ecosystem to recover from insults such as Hurricane Agnes. Diversity and species richness levels were reduced in the summer of 1972 following Agnes. While diversity recovered rather quickly, richness depression continued into 1973. Diversity and richness values had recovered in 1974, 1975, and 1976 and were not significantly different from one of the two preoperational periods used for comparison (Appendices H and P).

The majority of the benthic macroinvertebrate species collected during this study are classed as "estuarine endemic" and are characteristic of the meso- and oligohaline zones of the estuarine system of Chesapeake Bay (Table 10). As such, they are well adapted to the varying environmental conditions found around Surry Power Station. Since the transition zone is what it is, other species from both the upstream freshwater zone and downstream saline zone are found when suitable conditions exist.

Results of this study show that the benthic macroinvertebrate community, including shellfish, is not being appreciably harmed by the thermal effluent from Surry Power Station. Changes within the community have been correlated with natural changes as well as sediment type.

TABLE 10: ECOLOGICAL CLASSIFICATION OF BENTHIC MACROINVERTEBRATES FOUND IN THE OLIGOHALINE JAMES RIVER*

Estuarine Endemic	Other
Scolecolepides viridis	*Tubulanus pellucidus* (polyhaline)
Laeonereis culveri	*Nereis succinea* (euryhaline)
Oligochaeta	Dipteran larvae (freshwater to oligohaline)
Hydrobia sp.	*Lepidactylus dytiscus* (euryhaline)
Congeria leucophaeta	*Corbicula manilensis* (freshwater to oligohaline)
Rangia cuneata	*Brachidontes recurvus* (meso- to euhaline)
Macoma balthica	*Polydora ligni* (oligo- to euhaline)
Macoma mitchelli	*Edotea triloba* (euryhaline)
Cyathura polita	*Monoculodes edwardsi* (euryhaline)
Chiridotea almyra	
Gammarus spp.	
Leptocheirus plumulosus	
Corophium lacustre	
Rhithropanopeus harrisii	

* Adapted from Appendix G.

C. FOULING ORGANISMS

A series of fouling plate stations was established in the James River around Surry Power Station in January, 1971. Studies on the organisms colonizing the plates have continued since that time. This community has shown no effect from the thermal effluent from Surry Power Station (Appendices H and P).

Throughout the six years that this trophic level has been under study the fouling plates have been colonized mainly by barnacles, ectoprocts, hydroids, and one species of amphipod of the genus *Corophium*. Other forms have been found in reduced numbers. With the exception of 1972 following Hurricane Agnes, the largest numbers of species and individuals within species have been collected in August and October of each year. Temporal distribution patterns related to normal seasonal cycles of temperature and salinity have been displayed.

Two species were dominant during the entire study period and these have shown no changes in population density or structure attributable to the thermal effluent from Surry Power Station. Barnacles of the genus *Balanus* exhibited similar temporal patterns in all years of the study except 1972 when Hurricane Agnes resulted in reduced salinity levels in the area (Fig. 13). Comparison of fouling plate data with plankton data (which sample barnacle nauplii) and benthic data (which sample adults on a monthly or quarterly basis) shows the superiority of fouling plates for sampling organisms of this genus (Fig. 14). While plates yield samples integrated over time, plankton sampling can miss periods of nauplier abundance and benthic sampling for adult barnacles is dependent on a suitable substrate. All three methods, however, gave results showing no influence from the thermal effluent.

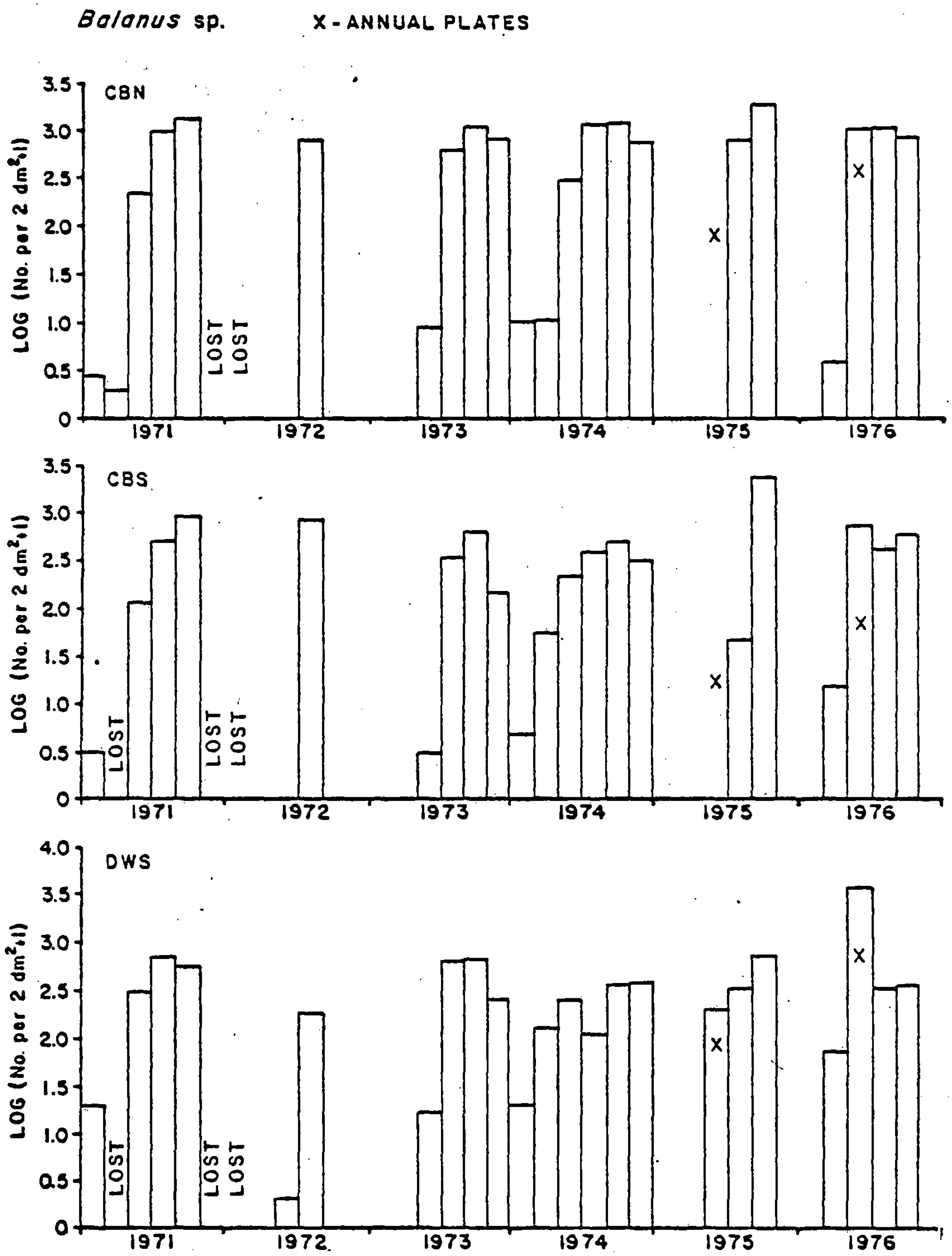


Figure 13: Temporal distributions of Balanus sp. population densities at the three fouling plate stations, 1971-76. (from Appendix P)

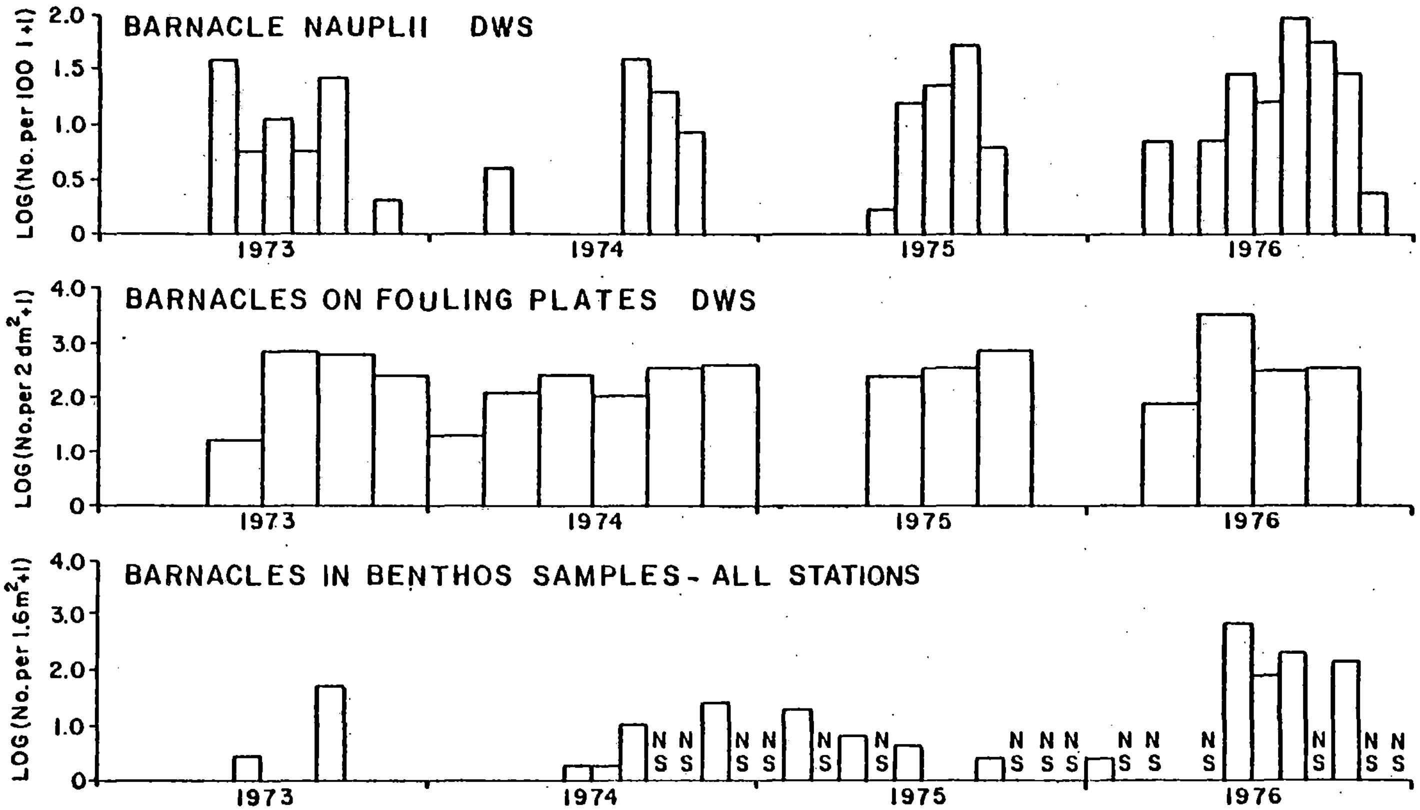


Figure 14: Temporal distributions of barnacle nauplii and Balanus sp. adults at fouling plate station DWS, and of Balanus sp. adults at all benthos stations combined; 1973-76. (NS = not sampled) (from Appendix P)

Amphipods (Corophium lacustre), while not considered a fouling organism, were opportunistic in seeking suitable habitat and consequently comprised the other dominant species collected during this study. Population densities for this species were highest in late summer or early fall at all stations in the six study years (Fig. 15). Specimens were collected in June of each year except 1971 and 1974 when they appeared on the fouling plates in February. The winters of 1970-1971 and 1973-1974 were relatively mild throughout the Chesapeake Bay system and resulted in the early collections.

Fouling organism populations, on the whole, exhibited seasonal variation patterns that changed from year-to-year in response to natural factors. No evidence has been found of any appreciable adverse effects from the thermal effluent from Surry Power Station (Appendices H and P).

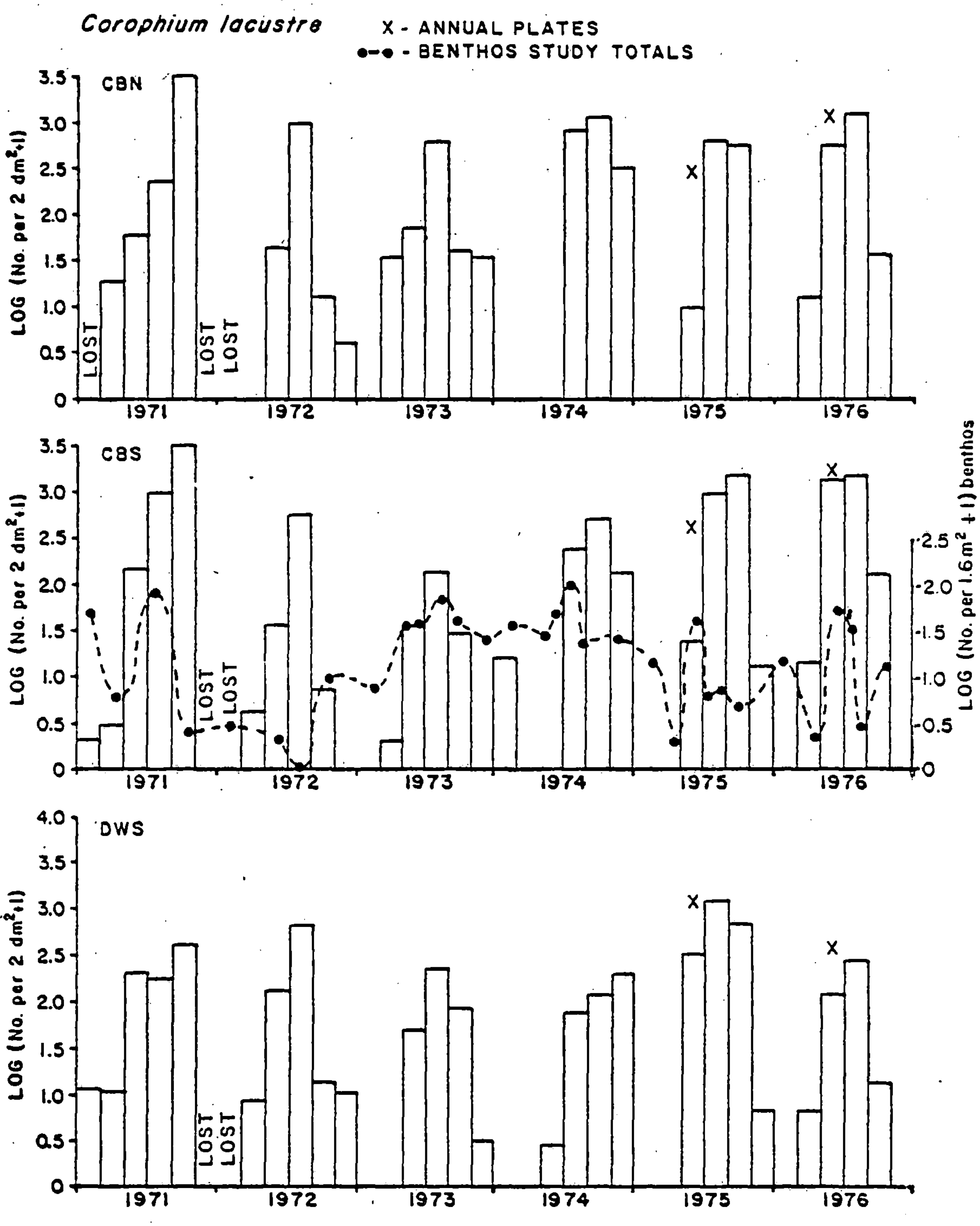


Figure 15: Temporal distributions of Corphium lacustre population densities at the three fouling plate stations and at all benthos stations combined, 1971-76. (from Appendix P)

D. ZOOPLANKTON

The James River zooplankton community is composed of two groups: the true zooplankton (holoplankton), and the meroplankton. The true zooplankters are generally present in varying numbers all year while the meroplankters are seasonal additions to the community, present only during times of reproduction. Those meroplankton discussed in this section include only the larval forms of benthic and fouling organisms. Ichthyoplankton, the other component of the meroplankton, are discussed in the finfish section.

Zooplankton studies have been conducted on a monthly schedule since November, 1972 by personnel of VIMS (Appendices H and P). Seven river stations were sampled in 1972-1974, twelve stations in 1975 and ten in 1976. These samples are taken with a 12.5 cm diameter Clarke-Bumpass quantitative sampler equipped with a No. 20 net. In addition to these river surveys, studies were designed and data taken to determine the effects of plume entrainment. Vertical distribution, vertical migration and the ranges of abundance of major zooplankton groups during a twenty-four hour period were also determined.

Throughout the study there has been a relative paucity of zooplankton in the area. This finding was not unexpected since it is typical of most turbid estuarine transition zones. As with preoperational sampling, copepod nauplii are the dominant forms in postoperational times (Fig. 16). Rotifers, likewise, are a dominant (Fig. 17) and both show, along with most other species, considerable variation due to tidal, diel, salinity, and seasonal influences (e.g., Fig. 18 showing variability of <u>Bosmina</u> sp.). Normally freshwater species such as <u>Bosmina</u> are most abundant when salinity levels fall below one ppt.

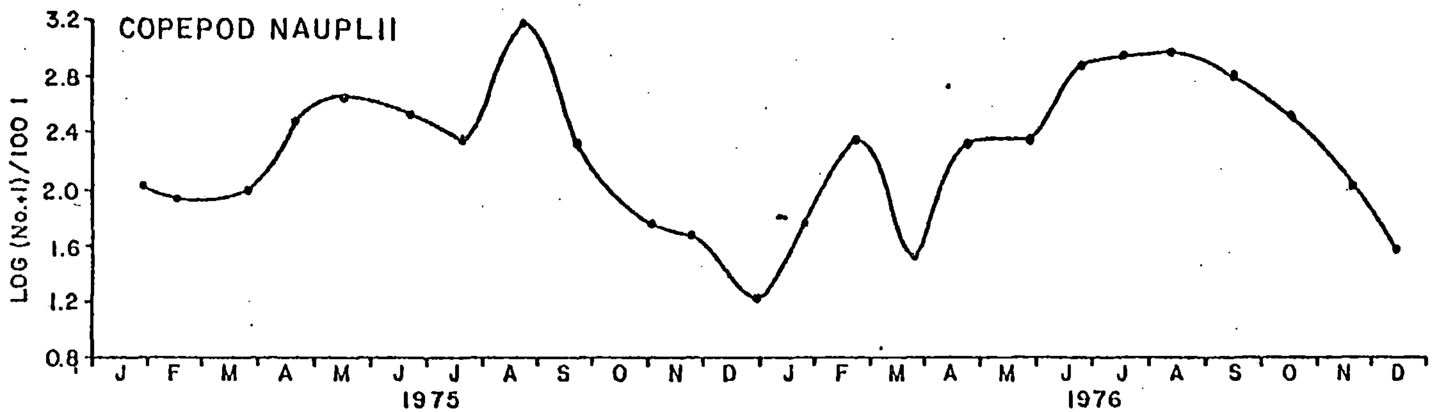


Figure 16: Population densities of copepod nauplii in the study area, 1975-76; means over nine stations. (from Appendix P)

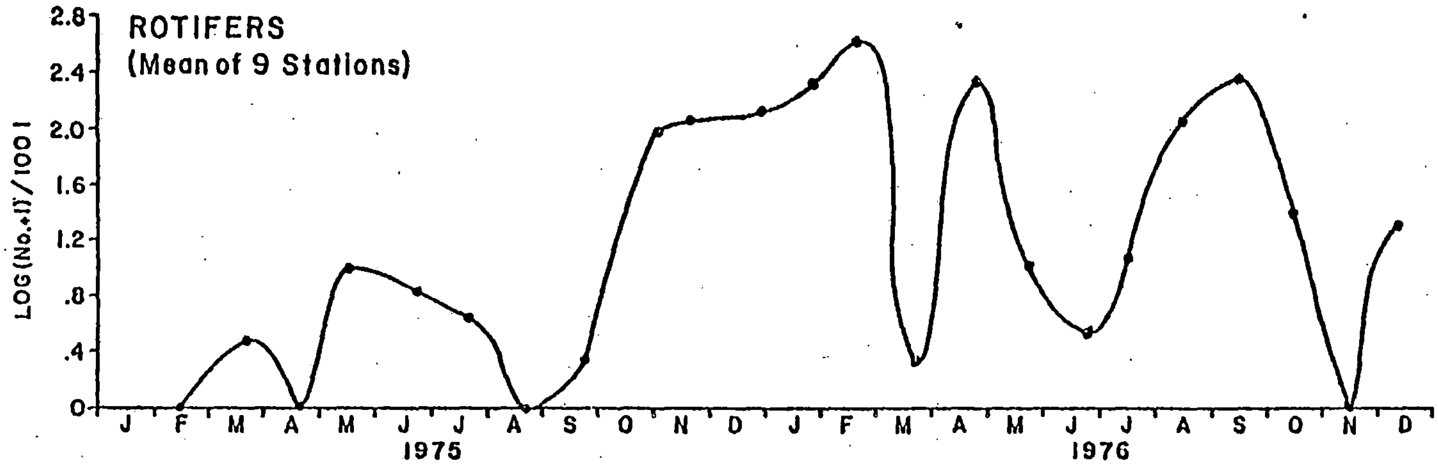


Figure 17: Population densities of rotifers in the study area, 1975-76; means over nine stations. (from Appendix P)

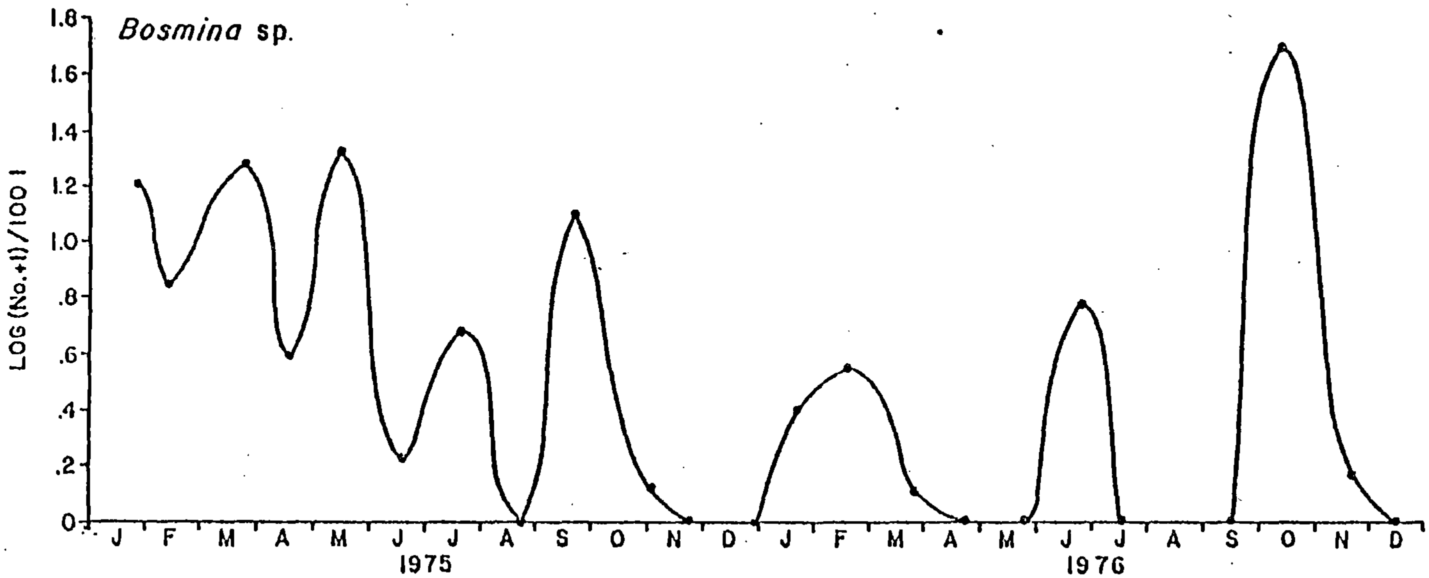


Figure 18: Population densities of Bosmina sp. in the study area, 1975-76; means over nine stations. (from Appendix P)

As to true zooplankters, the oligohaline zone of the James River was usually dominated by two genera of copepods: *Acartia* and *Eurytemora*. These dominants were joined by rotifers and cladocerans during low salinity conditions and by larvae of gastropods, polychaetes, and pelecypods during normal reproductive seasons.

Meroplankton larval forms of benthic and fouling organisms were sampled as an inseparable component of the holoplankton. Normal seasonal patterns of abundance were observed with additions to the community by barnacle nauplii from June to September (Fig. 19), polychaete larvae from June to December (Fig. 20), gastropod larvae from June to September, and pelecypod larvae from June to September. The only apparent effect of the Surry discharge was an addition of barnacle nauplii to the river in August and September. However, these are not considered to be a nuisance species.

Analyses were designed to determine significant differences in plume and non-plume areas of the river. Analyses were conducted on all parameters using a variety of approaches, including analysis of variance. Considerable variability in abundance was found within and between stations in and out of the thermal plume, as well as months and seasons. Variation also occurred over depth, tide, and time of day. VIMS concluded from such analyses that the heated effluent from Surry Power Station was not affecting the zooplankton community in the oligohaline zone of the James River.

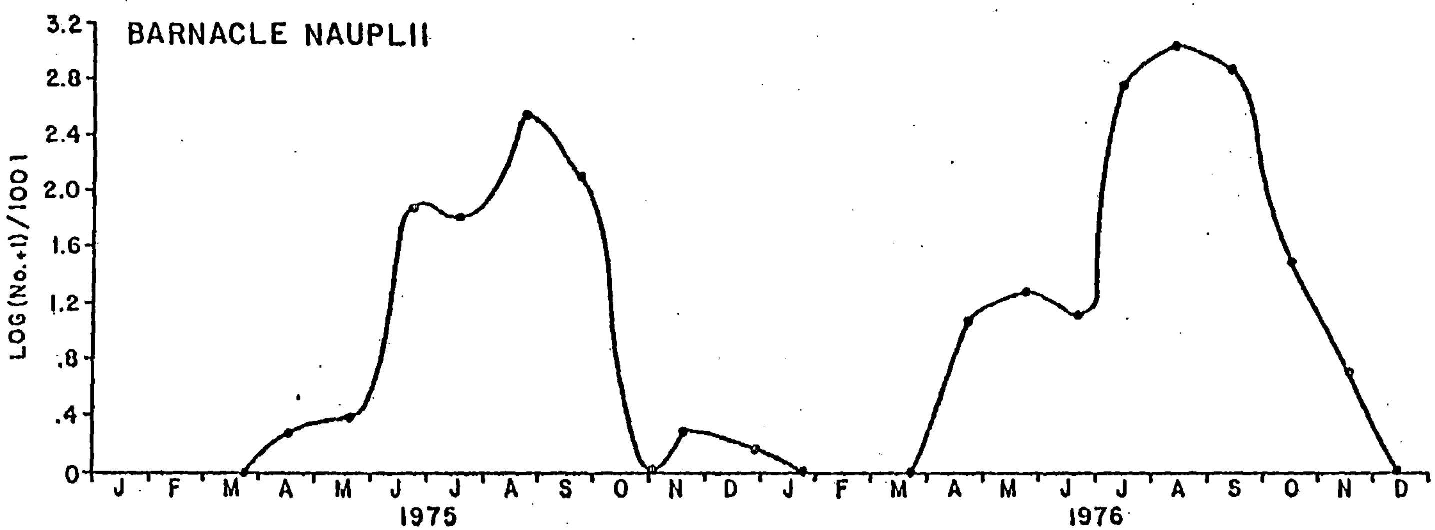


Figure 19:. Population densities of barnacle nauplii at the Surry Power Station discharge, 1975-76. (from Appendix P)

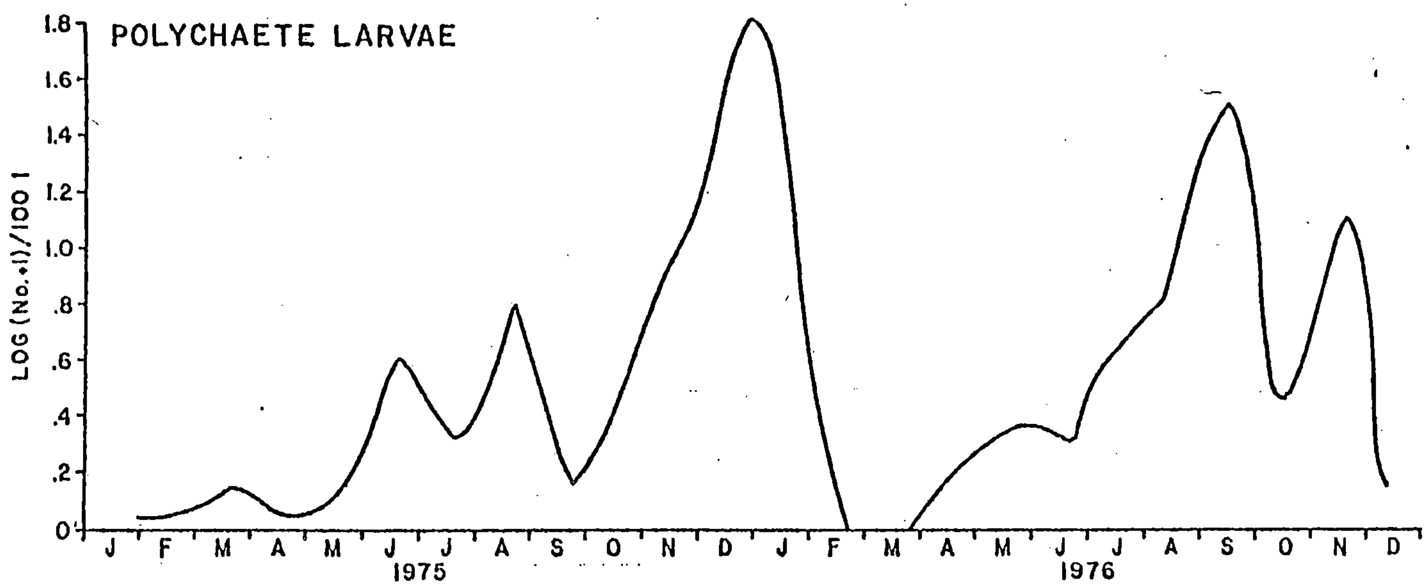


Figure 20: Population densities of polychaete larvae in the study area, 1975-76; means over nine stations. (from Appendix P)

E. PHYTOPLANKTON

Phytoplankton populations in the oligohaline zone of the James River have been under study since the late 1960's, largely by personnel of the Virginia Institute of Marine Science (Appendices H and P). Populations were characterized, and the effects of Surry Power Station thermal discharge determined, by at least four methods commonly utilized in such studies: primary production, chlorophyll $\bar{a}$, total cell counts and identification, and community structure (See VII for details). The major conclusion reached by VIMS during preoperational studies was that the oligohaline zone of the James River is one of low productivity (Appendix I), a conclusion affirmed during operational studies. Subsequently, through operational studies, VIMS concluded that the thermal effluent of Surry Power Station was not appreciably harming the diatom-dominated phytoplankton community of the river (Appendices H and P). There were two main reasons for the findings of low productivity. Populations are naturally low in the transition zone because it is the interface zone between fresh and salt water, a relatively hostile environment for all but the hardiest of species. Also, the zone is an area of high turbidity which reduces light penetration levels which in turn reduce plankton levels.

As stated previously, oligohaline or transition zones, such as the one near Surry Power Station, usually have low levels of phytoplankton because of fluctuating levels of salinity and because this zone is one of high turbidity resulting in reduced levels of light penetration. Employing several of the accepted methods for the characterization and evaluation of estuarine phytoplankton communities, it has been determined that although transition zone phytoplankton populations at times are diverse assemblages of flora, the thermal effluent from Surry Power Station is not causing appreciable harm to them. Dominance shifts and total density fluctuate seasonally in response to natural temperature conditions and the number of species (or community structure) varies in response to salinity (Appendices H and P).

Primary production in the James River transition zone has been determined to be generally very low. Primary production is basically the production of organic matter from inorganic materials per unit of time by autotrophic organisms (e.g., phytoplankton) with the aid of radient energy and is measured in terms of milligrams of carbon. Preoperational studies have shown most wintertime levels to be below 0.1 $mgC \cdot m^{-3} \cdot hr^{-1}$ with 87% of the annual measurements below 5 $mgC \cdot m^{-3} \cdot hr^{-1}$ (Appendices D and I). These low levels were due in part to extreme tidal variations in temperature and salinity and to high turbidities (e.g., Secchi disk readings ranged from 0.1 m to 1.0 m). Postoperational studies by VIMS tended to confirm those levels found prior to station operation in that 85% of the values obtained were below 5 $mgC \cdot m^{-3} \cdot hr^{-1}$ (Appendices H and P) indicating that the thermal effluent from Surry Power Station is not harming productivity in the phytoplankton community.

Chlorophyll a determinations, as measured in micrograms or milligrams per liter, provide a relative measure of the standing crop of phytoplankton, and were made during both preoperational and operational times (Appendices I, H and P). Variability was the rule within and between seasons and within and between stations. Generally, those measurements from July, 1972 through December, 1973 showed values ranging from 1.8 $\mu g \cdot l^{-1}$ in November, 1973 to 5.0 $\mu g \cdot l^{-1}$ in June, 1973. Studies in 1975 revealed ranges from 1.5 $\mu g \cdot l^{-1}$ in December to 5.3 $\mu g \cdot l^{-1}$ in July (Appendix H). Additional studies conducted in 1976 showed mean surface values ranging from 1.6 $\mu g \cdot l^{-1}$ in November to 6.7 $\mu g \cdot l^{-1}$ in April (Appendix P).

Investigations of tidal James River phytoplankton populations in 1968 and 1969 showed similar values with few measurements exceeding 10 $\mu g \cdot l^{-1}$ (Appendix D). Levels exceeding 50 $\mu g \cdot l^{-1}$ are considered indicative of overenrichment. The results by VIMS show that the thermal effluent is not influencing the standing crop of phytoplankton in the river.

Finally, phytoplankton populations have been studied through total cell counts and identification (Appendices H and P) with 1973 through 1976 samples having been analyzed quantitatively. In 1973 and 1974, VIMS found that the lowest counts were obtained in January which had ranges of 50-400 $cells \cdot ml^{-1}$ (1973), and 30-150 $cells \cdot ml^{-1}$ (1974). Yearly maxima occurred in the summer with ranges of 3,000-7,500 $cells \cdot ml^{-1}$ in June, 1973 and 1,550-5,200 $cells \cdot ml^{-1}$ in August, 1974. Similar results were obtained by VIMS in 1975 and 1976 (Fig.21), who concluded that there were no harmful effects from the thermal plume on cell counts.

Community structure in the James River was also similar in all of the years studied (Appendices H and P) although structure changes due to pumping were infrequently noted in the discharge canal. Dominant genera included four diatoms (*Nitzschia*, *Melosira*, *Cyclotella*, *Skeletonema*) and one cryptophyte (*Chroomonas*). As might be expected, periodic within-community dominance shifts occurred which were related to salinity fluctuations in the transition zone. Extreme, but natural, variability within species was the rule rather than the exception (Fig. 22). No effect on community structure could be related to the thermal effluent by VIMS.

During 1975, intensified studies were conducted to determine diel and vertical distributions of phytoplankton populations (Appendix H). These intensified studies were conducted in addition to the regular monthly samples

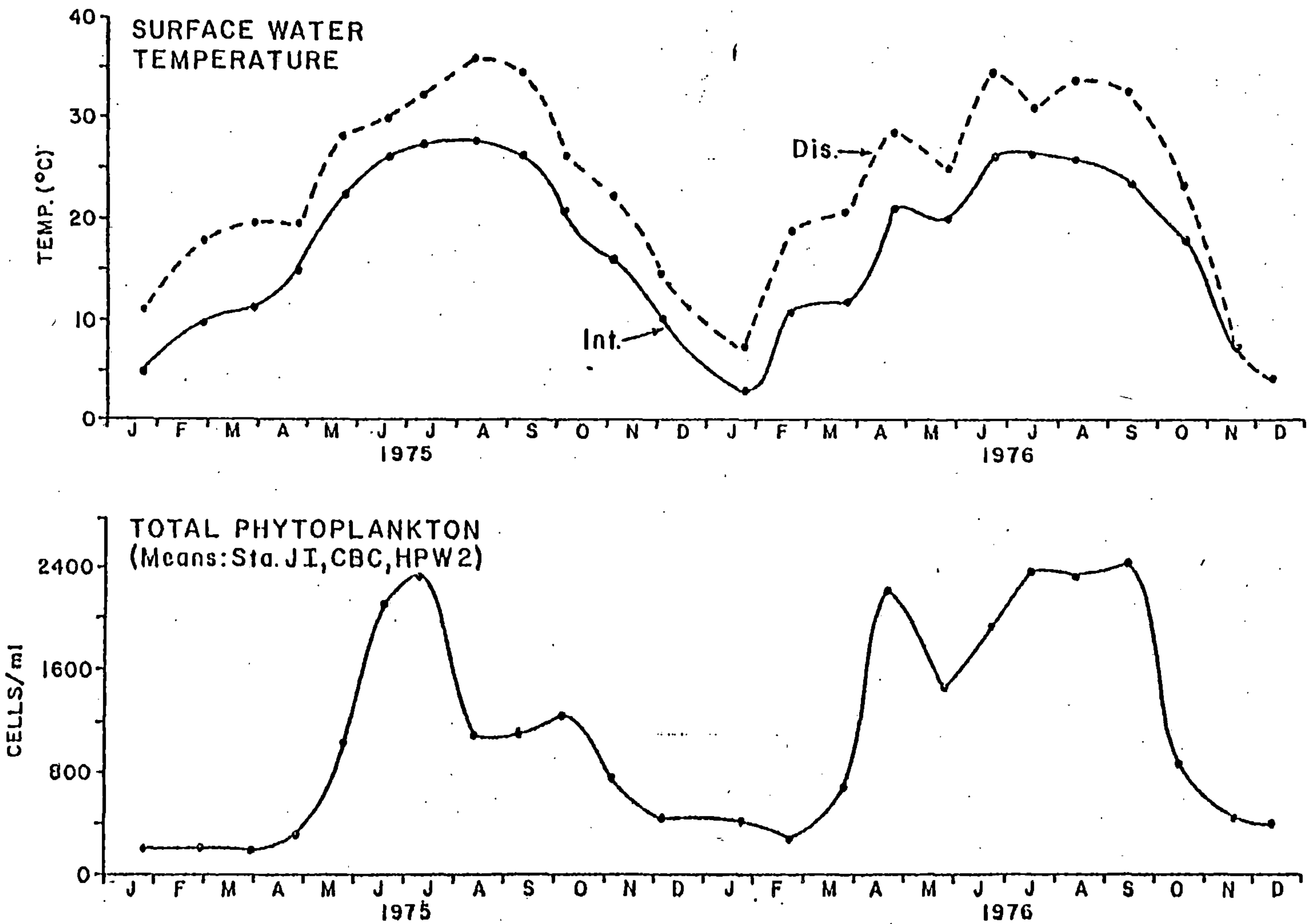


Figure 21: Surface water temperature and total phytoplankton abundance in the study area, 1975-76. (from Appendix P)

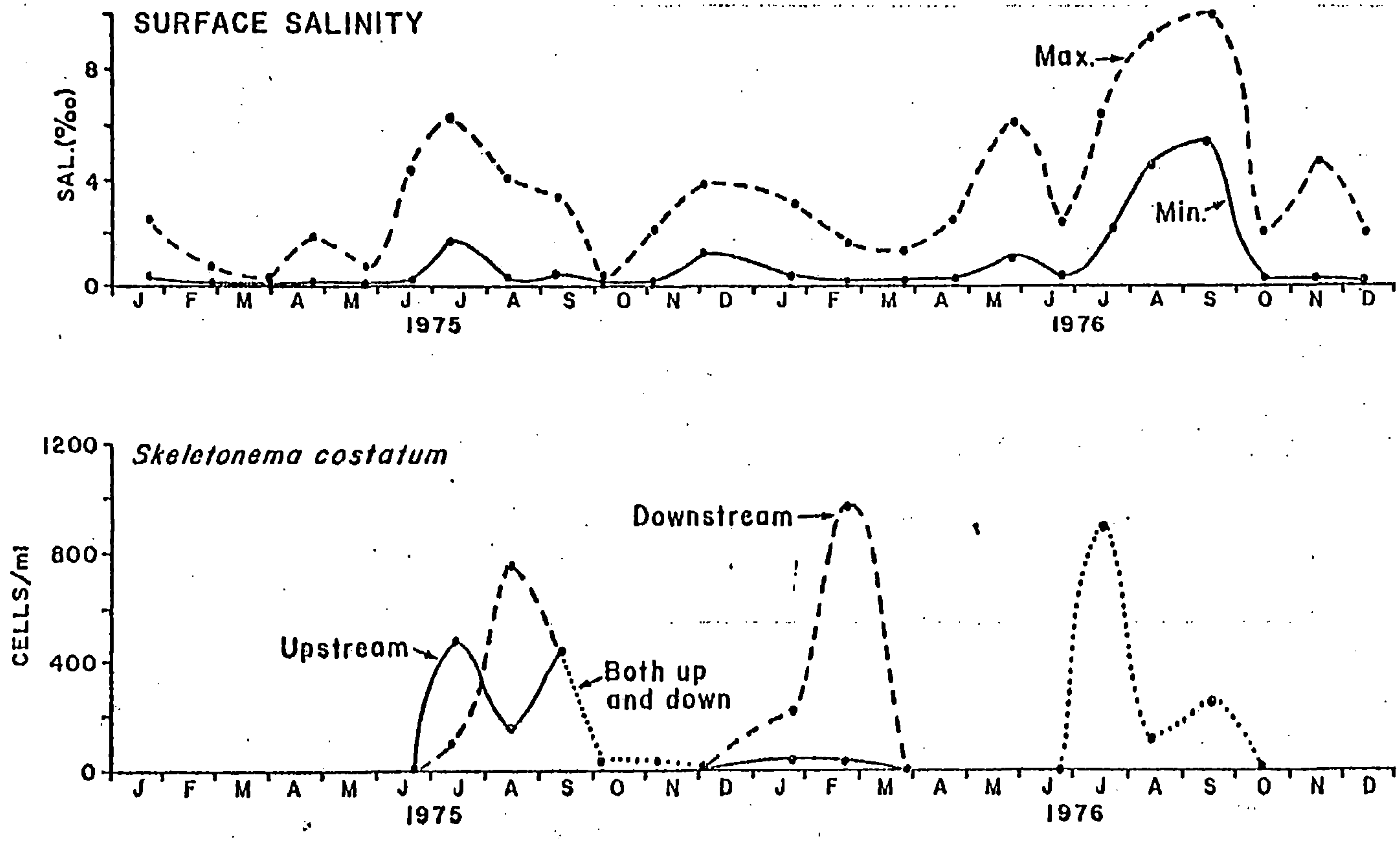


Figure 22: Surface salinity and Skeletonema costatum abundance in the study area, 1975-76. (from Appendix P)

taken at 12 river stations. Vertical distribution samples were taken at each of the 12 stations three times during the year. Diel distributions were determined by sampling at a single station for three 24-hour periods during the year.

Basically, the data indicate that the maximum abundance of phytoplankton occurs during daylight hours (justifying the validity of daytime sampling), and that abundance is relatively uniform over depth (justifying the validity of replicate surface samples). Similar studies in 1976 tended to confirm these results (Appendix P).

The one influence of power station operations that was observed by VIMS occurred in the warmer months of some, but not all, years and appeared to have been limited to the discharge canal system and to a very small area of the river immediately outside of the discharge canal mouth. The effect consisted of slightly reduced or increased numbers of cells in the discharge area which is well within the prescribed mixing zone for Surry Power Station. It should be pointed out that this effect was measured within the discharge canal and immediate vicinity and that there has been no detectable impact on the phytoplankton population in the James River. VIMS found that the effect was due largely to pumping operations and the resultant transport of organisms based on their comparative upstream/downstream densities. Discharge canal decreases occurred when downstream intake waters were poorer in plankton than upstream waters. The reverse was true at times when downstream areas were richer in plankton, and slight increases outside the discharge canal would occur from pumping augmentation. Once again, this increase or decrease could not be detected in the zone of the river beyond the immediate discharge area.

Studies by VIMS concluded that there is little likelihood that the discharge is altering the indigenous community and appreciable harm to the balanced indigenous phytoplankton population is not occurring nor is likely to occur as a result of the heated discharge from Surry Power Station. While the presence of blue-green algae species was noted, VIMS found no evidence to suggest that a shift toward nuisance species of phytoplankton had occurred nor was it likely that it would occur.

Further reading into the effects of Surry Power Station operation on phytoplankton populations in the oligohaline reach of the James River may be found in Appendices H and P.

F. THREATENED AND ENDANGERED SPECIES

The following species, whose known or suspected range includes the area of the Surry Power Station, have been officially classified as endangered or threatened by the U. S. Fish and Wildlife Service:

Mammals - none.

Birds -

Southern Bald Eagle, Halieetus leucocephalus leucocephalus
American Peregrine Falcon, Falco peregrinus anatum
Arctic Peregrine Falcon, Falco peregrinus tundrius
Brown Pelican, Pelecanus occidentalis
Kirtlands Warbler, Dendroica kirtlandii
Red Cockaded Woodpecker, Dondrocopos borealis.

Reptiles - none.

Fish -

Shortnose Sturgeon - Acipenser brevirostrum.

Snails - none.

Clams - none.

Insects - none.

Plants - none.

None of the named species has been, or is likely to be, affected by the thermal discharge from Surry Power Station. Two Southern Bald Eagles are known to reside on the Hog Island Wildlife Refuge, feeding largely in the freshwater ponds on the island. Shortnose sturgeon are suspected to occur in Chesapeake Bay and its tributaries although none have been reported from the James River in recent years and none were taken during VIMS and Vepco fish surveys.

G. VERTEBRATES OTHER THAN FINFISH

The location of Surry Power Station near the oligohaline zone of the James River precludes the presence of most aquatic vertebrates other than finfish. For example, there are no manatees, sharks, or whales in the area. Other major vertebrates in the area include the ducks and geese found on the Hog Island Wildlife Refuge. These species are in no way adversely affected by the heated effluent from Surry Power Station.

XI. SUMMARY

The foregoing demonstration contains all of the information necessary to meet the statutory and regulatory standard for a successful Section 316(a) demonstration. Vepco has conclusively demonstrated in this document and the attached appendices that no appreciable harm has resulted from the thermal component of the Surry Power Station discharge to the balanced, indigenous community of shellfish, fish, and wildlife in and on the James River into which the discharge has been made.

XII. APPENDICES

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